NEXT-GEN RACE CARS REVEALED

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

THE GAMING PHENOMENON EXPLAINED!

SECRETS OF THE SPECIAL FORCES

SUPER DRONES

MEET THE ROBOTS EXPLORING ALIEN WORLDS, UNCOVERING ANCIENT SECRETS & HELPING HUMANITY

+ LEARN ABOUT

- RICHARD FEYNMAN
- OCEAN CURRENTS
- WIND TUNNELS
- CAMP STOVES
- DRY SHAMPOO
- HUMAN CELLS
- ELECTRICITY
- ELEMENTS
- CAMERAS
- PIMPLES
- LI-FI

EXPLORE REAL-LIFE STAR WARS WORLDS

ANCIENT EGYPTIAN AFTERLIFE

The gods, demons & rituals of the underworld explained

TYPES OF FAT

Get the skinny on the role different fats play

BECOME AN ASTRONAUT

Find out how to launch your career in space

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THE SCIENCE OF CITIES

Why power lines buzz & skyscrapers stay up

GENTOO PENGUINS

Discover the life cycle of these Antarctic animals


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ISSUE 89

WELCOME

The magazine that feeds minds!

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"We can look to current tech in motorsport to understand what lies ahead for road travel"

Next-gen race cars, page 48

Meet the team...

Dave
Editor-in-Chief
It's amazing to think that lots of the current tech in motorsport will soon feature in everyday road cars. Find out what the future holds in next-gen race cars on page 48.

Katy
Research Editor
The Ancient Egyptians went to a lot of trouble to secure themselves a ticket to the underworld. It's a shame they had their brains scooped out before they set off, though!

Jack
Senior Staff Writer
I love everything to do with *Star Wars* (except Jar Jar Binks), so the fact that there may be a real-life Alderaan that hasn't been blown up by the Empire comforts me.

Duncan
Senior Art Editor
I knew being in the Special Forces wasn't easy, but reading about the gruelling selection process and training regimes involved has made me reconsider that SAS application...

FOLLOW US... How It Works magazine @HowItWorksmag

Drones: is there anything they can't do? From surveillance to space travel, deliveries to defence, these flying droids have many applications beyond warfare. They are used to protect endangered species and scout for ancient ruins, and could soon explore the Solar System on our behalf.

I'll let you in on a little production secret (a peek behind the **How It Works** curtain if you like!): the entire feature stemmed from the idea of 'Indiana Drones'. While it wouldn't necessarily make a great blockbuster, drones would certainly make Indy's life a lot easier.

Also in this issue, we discover the lives of the world's elite military units: the intense training and high-tech gear used by the super soldiers of the Special Forces. Our space feature explores the real-life examples of worlds from a galaxy far, far away... while back on Earth we reveal the future of motor racing, uncover the Ancient Egyptian afterlife, and discover some amazing facts about our primate cousins. Enjoy the issue!

Jackie **Jackie Snowden**
Deputy Editor

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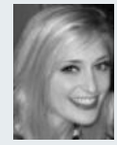
Meet the experts...

Alicea Francis
As a fan of all things Ancient Egypt, who better than Alicea to explain the traditions and superstitions of the afterlife? Discover the elaborate rituals of mummification and burial on page 78.

Lee Sibley
Total 911's Lee takes a look at the tech and engineering that drivers will soon see on the racetrack. He also talks endurance racing tech and tactics with Le Mans 2015 winner Nick Tandy.

Jonny O'Callaghan
This month, *IFL Science* reporter Jonny takes us on a tour of the moons and planets that resemble the exotic locations of everyone's favourite sci-fi franchise.



Ella Carter
From tool use to emotional intelligence, Ella reveals the amazing lives of chimps, gorillas, bonobos and orangutans in our fact-packed ape feature.

Stephen Ashby
From the Indiana Drones of archaeology to the as-drone-noughts of the future, Steve explains how these super flying bots are giving us a helping hand.

REGULARS

HOW IT WORKS **Reader Survey**

Have your say on **How It Works!**

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We love making **How It Works** and we hope you love reading it too. But we want to keep making it even better, so we're asking for your help. By answering just a few questions, you could be selected to join our latest **How It Works** panel. We're so excited to hear what you have to say and can't wait to learn more about you.

Jackie

Jackie Snowden
Deputy Editor

HOW IT WORKS

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A place on our reader panel, giving you regular input on the magazine

Step 1 Complete survey → **Step 2** Get involved → **Step 3** Earn rewards

Complete our survey & join the team today

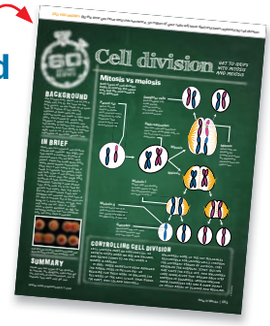
howitworksdaily.com/survey2016

Three changes you asked for in 2015

Last year we used your input to make some fantastic improvements, including…

1 Reviews of the latest books
After discovering you were all keen readers we started reviewing our favourite new releases.

2 60 second science
An all-new, regular feature that explains key scienctific in principles in under a minute.



3 "Day in the life" interviews
Readers can now get a behind-the-scenes look at exciting jobs in the world of science and tech.

Pokémon Go: the pocket monsters return

The tech behind the innovative game taking the world by storm

Just weeks after its release, *Pokémon Go* is already a cultural phenomenon. 20 years after the pocket monsters first hit our Game Boys, this latest craze allows fans to become real-life Pokémon Masters using their smartphones.

Pokémon Go uses your phone's GPS signal and real-world map data to figure out where you are and what is around you. A virtual world is then superimposed on your phone's map, displaying nearby Pokémon and points of interest.

The game's algorithms determine when and where Pokémon can be found. Data about your location, such as temperature and terrain, can also be used by the programme to create 'hotspots' of particular creature types. For example, if you wander into a nearby park, grass-based Pokémon will often be found, whereas near the coast you're more likely to encounter water monsters.

Pokémon Go uses augmented reality to bring the cartoon creatures to life. By combining the game data with the view from your phone's camera, the virtual Pokémon you are trying to catch is overlaid onto your surroundings, giving the impression that the monster is right in front of you.

Pokémon Go is already the most popular mobile game in US history and its success paves the way for many more augmented reality games to come. Server overloads from the sheer number of players aside, it doesn't look like *Pokémon Go*'s meteoric rise is going to slow any time soon.

Why Pokémania makes you happy

The first Pokémon video game may have appeared on British shores 17 years ago, but now everybody is catching pocket monsters like it's 1999. *Pokémon Go*, like many other mobile games, encourages you to complete a series of simple tasks. This stimulates reward pathways in your brain, so every time your Pokéball closes on a Pikachu, the neurotransmitter dopamine is released, making you feel happy. The game is designed to be played on the go, so players also get the benefits of exercise, which produces endorphins. Another feature not to underestimate is the 'FOMO' phenomenon, or the 'fear of missing out'. When you witness someone enjoying the game, brain cells known as mirror neurons produce oxytocin that creates the urge to experience what is making other people smile. This combination of happiness hormones and chemicals, along with the lure of envy, is what makes *Pokémon Go* so popular, and even addictive to some.

POKÉMON GO IN NUMBERS

The amazing stats the mobile game is already generating

56%
JUMP IN NINTENDO'S SHARE PRICE FOLLOWING *POKÉMON GO*'S RELEASE

10%
OF MICROTRANSACTION REVENUES ESTIMATED TO GO TO NINTENDO

75 million
DOWNLOADS ESTIMATED BY 27 JULY

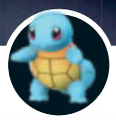
350,000
PEOPLE IN THE UK
WERE PLAYING *POKÉMON GO* BEFORE ITS OFFICIAL RELEASE THANKS TO ANDROID APK DOWNLOADS AND AMERICAN APP STORE ACCOUNTS

47%
OF ALL IN-APP PURCHASES ON 10 JULY 2016 WERE CREDITED TO *POKÉMON GO*, ACCORDING TO SLICE INTELLIGENCE

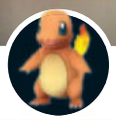
10.8%
OF ANDROID DEVICES IN US ESTIMATED TO HAVE *POKÉMON GO*

Where to find Pokémon

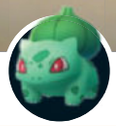
The spawn locations you should be looking out for



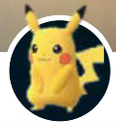
WATER
BEST SPAWN RATES:
Rivers, streams, lakes, ponds, docks, beaches, oceans, canals
GOOD SPAWN RATES:
Wetlands, parks



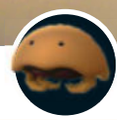
FIRE
BEST SPAWN RATES:
Farmland, arid areas
GOOD SPAWN RATES:
Cities, residential areas, beaches, parks



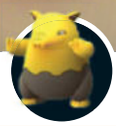
GRASS
BEST SPAWN RATES:
Gardens, parks, golf courses, woodland
GOOD SPAWN RATES:
Farmland, hiking trails, nature reserves



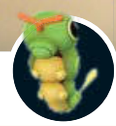
ELECTRIC
BEST SPAWN RATES:
University and college campuses
GOOD SPAWN RATES:
Cities, concreted areas



ROCK
BEST SPAWN RATES:
Farmland, quarries, car parks
GOOD SPAWN RATES:
Hiking trails, nature reserves, parks



PSYCHIC
BEST SPAWN RATES:
Hospitals, cities
GOOD SPAWN RATES:
Residential areas (at night)

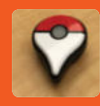


BUG
BEST SPAWN RATES:
Parks, golf courses, gardens, meadows
GOOD SPAWN RATES:
Farmland, woodland, nature reserves

Obsessive gamers have been warned about their safety when playing *Pokémon Go*

Unofficial companion tech

The must-have extras to complement and improve the *Pokémon Go* experience



Pokémon Go Plus

This piece of wearable tech allows the user to catch Pokémon with Bluetooth technology. An LED on the device flashes when Pokémon are near and a press of a button will throw your Pokéball in an attempt to catch it.

Poké Radar

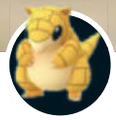
This app allows players to map where they've found rare Pokémon so others can get in on the action. There's a filter to the type of Pokémon you can find so if you badly want a Charizard, this is the app for you.

GoChat

Go Chat allows users to message other trainers for hints, tips and maybe a bit of gloating. There are three modes – local, regional and global – which allow players to converse over a radius of five kilometres, 100 kilometres or worldwide, respectively.

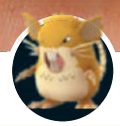
Poké VR

From augmented reality to virtual reality, *Poké VR* harks back to the popularity and success of the original anime and handheld games by allowing the player to see and catch wild Pokémon in the actual world they live in.



GROUND
BEST SPAWN RATES:
Farmland, woodland, quarries
GOOD SPAWN RATES:
Hiking trails, fields, golf courses, parks

POISON
BEST SPAWN RATES:
Wetlands, ponds, lakes
GOOD SPAWN RATES:
Industrial areas, large buildings



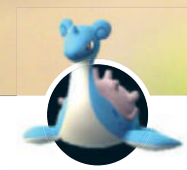
NORMAL
BEST SPAWN RATES:
University and college campuses
GOOD SPAWN RATES:
Residential areas, car parks

DRAGON
BEST SPAWN RATES:
Golf courses, landmarks
GOOD SPAWN RATES:
Places of interest

FAIRY
BEST SPAWN RATES:
Beaches
GOOD SPAWN RATES:
Landmarks, churches, cemeteries

FIGHTING
BEST SPAWN RATES:
Gyms, leisure centres
GOOD SPAWN RATES:
Stadiums, recreation areas

GHOST
BEST SPAWN RATES:
Churches, residential areas (at night)
GOOD SPAWN RATES:
Residential areas



ICE
BEST SPAWN RATES:
Bodies of water, ski resorts, glaciers
GOOD SPAWN RATES:
Grassy areas

The Juno spacecraft could help teach us more about the origins of the Solar System

The Juno team at NASA's Jet Propulsion Laboratory celebrate as the probe successfully enters orbit

TALKING POINT

Juno arrives at Jupiter

After a five-year journey, NASA's probe is ready to unlock the gas giant's mysteries

At 20:53 Pacific Daylight Time on 4 July 2016 the Juno spacecraft completed a 35-minute engine burn, successfully entering orbit around Jupiter, our Solar System's largest planet.

As Juno approached the gas giant, it is estimated to have reached record speeds of around 265,000 kilometres per hour relative to Earth. "I don't think we've had any human object that's moved that fast, that's left the Earth," noted Scott Bolton, Juno's principal investigator. Because of this immense speed, the probe had to execute its precise engine burn in order to slow down enough to be captured by Jupiter's gravity and enter orbit.

The scientific investigations won't begin in earnest until October, but in the meantime it is possible for some initial data to be gathered. "We've figured out a way to collect data a lot earlier than that" explains Bolton, "which, when you're talking about the single biggest planetary body in the Solar System, is a really good thing. There is a lot to see and do here."

The Juno mission will help scientists discover Jupiter's origins, which will improve our understanding of how the Solar System evolved. During its 20-month mission, the probe will map the planet's magnetic field and study the auroras, as well as determine the structure of Jupiter's core and composition of its atmosphere.

I am Jupiter, hear me roar

Jupiter's powerful magnetic field creates permanent auroras in its atmosphere

Jupiter has the most powerful magnetic field of all the planets in the Solar System. It is also the largest structure, extending as much as five astronomical units (five times the distance between Earth and the Sun) into space. If it were visible to us, it would appear to be twice the size of the full Moon in the night sky, despite being more than 2,000 times further away. As Juno soared through the gas giant's magnetosphere (the region of space where its magnetic field is dominant) on 24 June 2016, its instruments recorded an eerie sound. Jupiter's magnetic field effectively blocks the path of solar winds that blast through the Solar System at around 1.6 million kilometres per hour. As this supersonic stream of solar particles hits Jupiter's magnetosphere, it creates a bow shock – similar to a sonic boom on Earth – where the solar wind is heated and slowed down.

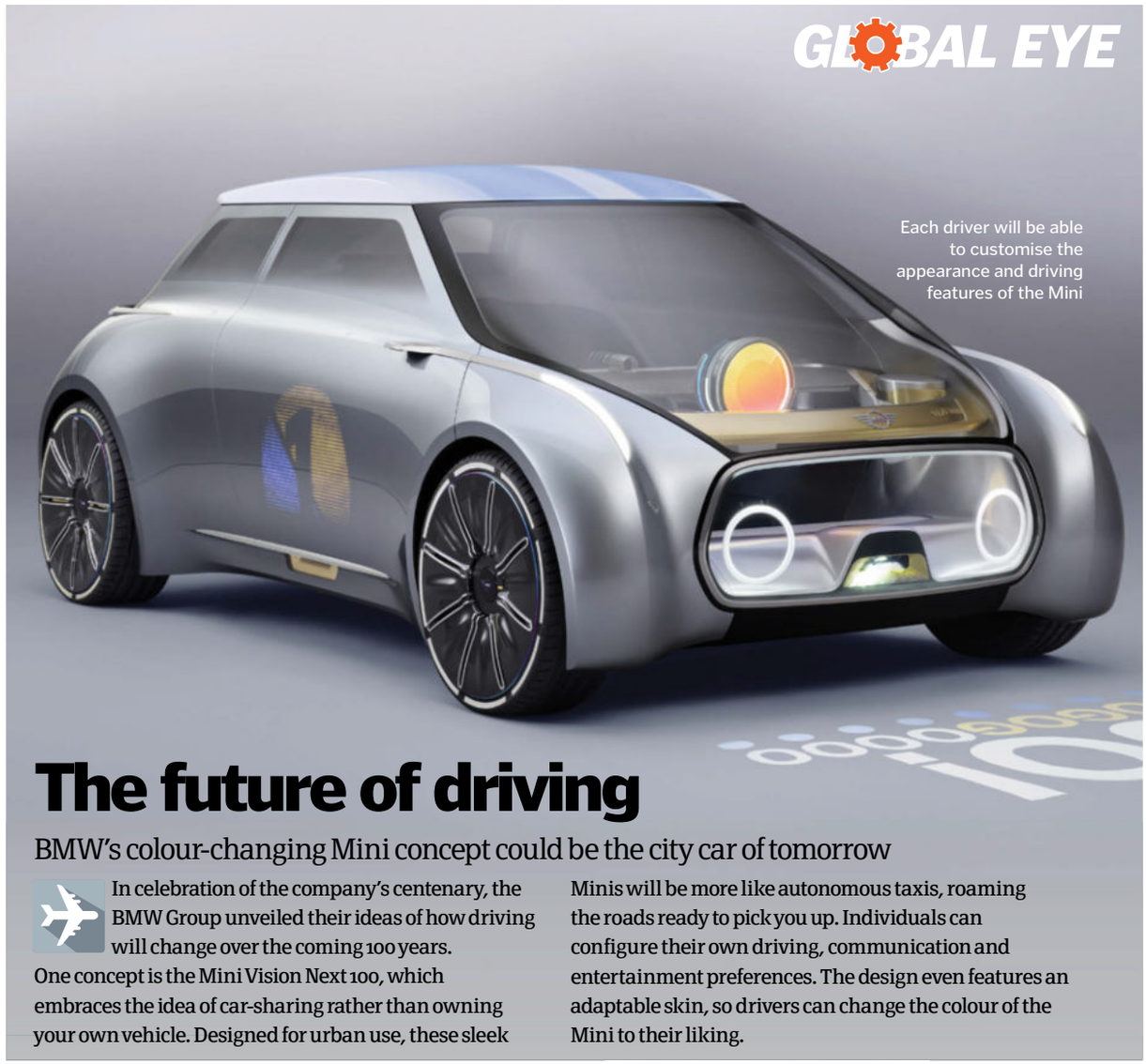
NEWS BY NUMBERS

1,287.5 km/h
The new land speed record the Bloodhound team intend to achieve in October 2017

750 gigaelectronvolts
The energy of a mysterious signal detected at the LHC, hinting at a new particle

4 mn km²
The amount by which the ozone hole has shrunk since 2000

$2
The cost of a new lab test that detects the Zika virus in saliva



Each driver will be able to customise the appearance and driving features of the Mini

The future of driving

BMW's colour-changing Mini concept could be the city car of tomorrow

In celebration of the company's centenary, the BMW Group unveiled their ideas of how driving will change over the coming 100 years. One concept is the Mini Vision Next 100, which embraces the idea of car-sharing rather than owning your own vehicle. Designed for urban use, these sleek Minis will be more like autonomous taxis, roaming the roads ready to pick you up. Individuals can configure their own driving, communication and entertainment preferences. The design even features an adaptable skin, so drivers can change the colour of the Mini to their liking.

The world's most powerful supercomputer

China develop machine capable of 93,000 trillion calculations per second

The Sunway TaihuLight at the National Supercomputing Centre in Wuxi, China, is now the most powerful supercomputer on the planet. Twice as fast and three times as efficient as its predecessor, the Tianhe-2, the TaihuLight will be used for weather forecasting, data analytics and manufacturing. While your average laptop features two or four core processors, TaihuLight contains over 10.5 million of them. During peak performance, the TaihuLight uses over 15 megawatts of electricity – that's enough to power over 10,000 homes at once.

The TaihuLight has 1.31 petabytes of primary memory

The captive zebra shark laid 41 eggs without fertilisation from a male, but only three hatched

Virgin shark gives birth

'Life finds a way' as aquarium shark has pups without a male

A zebra shark in an Australian aquarium recently gave birth to three pups, despite not having had contact with a male shark for years. Virgin birth, known as parthenogenesis, is rare but not unheard of in sharks. Cases of this phenomenon have also been reported in other animals, including snakes, lizards and birds. It's not clear why it happens, as it has a notable disadvantage: the offspring are half-clones of their mother. This reduces genetic diversity so they are more vulnerable to disease.

10 COOL THINGS WE LEARNED THIS MONTH

The biggest alien-hunting telescope has been built

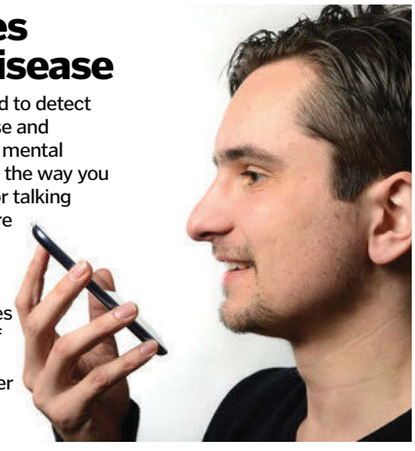
China begins the search for alien life in September 2016, with the completion of the world's largest radio telescope. The 500-metre-wide Aperture Spherical Telescope, or FAST, is the equivalent size of 30 football pitches and cost $180 million (£135m) to build. It's hoped that its monstrous size – almost double the size of the current record holder in Puerto Rico – will be able to detect the weakest of extraterrestrial signals. The Chinese government had to relocate 9,000 people to ensure radio silence in the area before the hunt begins.

There's an electric exoplanet

An exoplanet called Kepler-10b could experience trillions of lightning flashes in just one hour. Astronomers say the surface is made entirely of active volcanoes, and the dust from eruptions is what causes lightning. This makes the atmosphere extremely electric. On top of that, the daytime temperature is thought to be more than 1,370 degrees Celsius – hotter than lava flows on Earth.

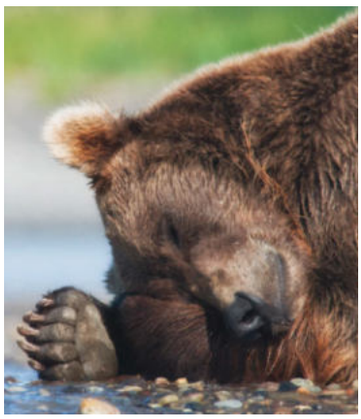
Patients' voices could reveal disease

Your speech could soon be used to detect conditions such as heart disease and depression. Some physical and mental diseases can cause you to alter the way you speak, such as slurring words or talking more nasally. These changes are usually so small that they wouldn't be noticeable to the ear in everyday conversation. However, technology companies are starting to develop types of software that will analyse speech patterns in much greater detail in order to help diagnose certain conditions.



Female birds look elsewhere for company

In the bird world, the ratio of males to females is skewed, and new research from the University of East Anglia explains why. Females 'fly the nest' in search of busy breeding sites, leaving behind small groups of lonely males. The more populated locations often have better habitats and males are more abundant. However, this means small populations are likely to decline even faster.



Bears are becoming lazy

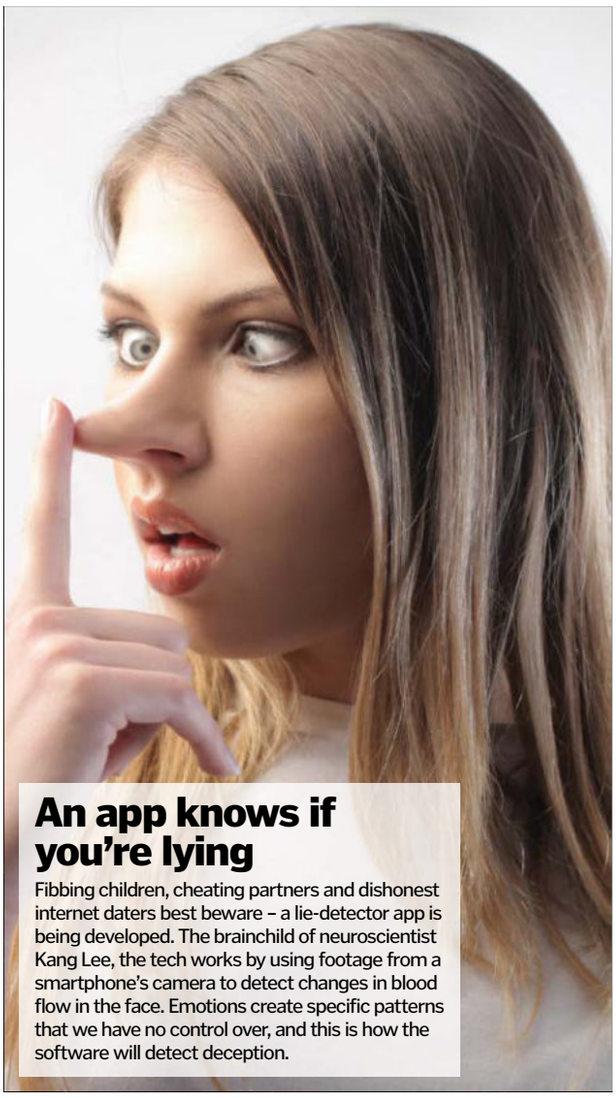
Raiding rubbish bins for food has turned brown bears into couch potatoes, a new study has found. 'Dump bears', as they're called, tended to stay close to garbage dumps, while bears that had never visited one travelled an average of 165 kilometres per year to find food.

Plastic from the UK ends up far away in the Arctic

Researchers tracked plastic rubbish floating in UK waters and found that it ended up in the Arctic within two years. Wind and ocean currents carry trash across the world where it can severely damage fragile ecosystems.

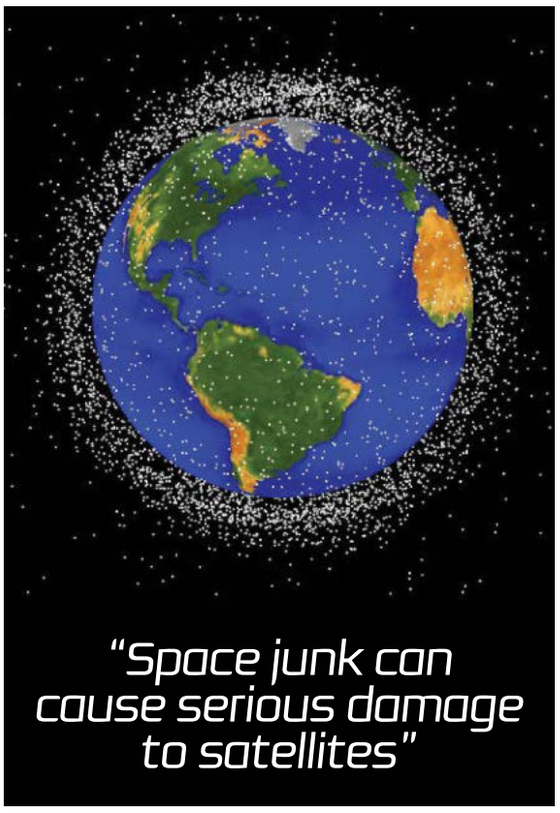
Pasta doesn't pile on the pounds

Despite what dieters have been led to believe, pasta is not fattening, and could even reduce the likelihood of obesity. Italian scientists carried out two studies examining the diets of over 23,000 adults, and found that pasta consumption was associated with the healthy Mediterranean diet, and linked with a better body mass index (BMI) and waist-to-hip ratio.



An app knows if you're lying

Fibbing children, cheating partners and dishonest internet daters best beware – a lie-detector app is being developed. The brainchild of neuroscientist Kang Lee, the tech works by using footage from a smartphone's camera to detect changes in blood flow in the face. Emotions create specific patterns that we have no control over, and this is how the software will detect deception.



"Space junk can cause serious damage to satellites"

Space needs a spring clean

Around 7,000 tons of space junk orbits Earth, and even the smallest piece can cause serious damage to satellites, including the International Space Station. In a bid to clean up space, the RemoveDebris mission, led by the Surrey Space Centre, will launch in 2017. It will use a variety of devices for litter picking, including nets and harpoons, in what will be one of the world's first missions to test methods of capturing space junk.

Cloning pets is pointless

Recently a couple in South Korea paid over £60,000 ($77,000) to clone their dead dog, but the scientist who created Dolly the sheep – the first cloned mammal – has warned it could be pointless. "In appearance and certainly personality it's likely to be very different," commented Professor Sir Ian Wilmut. He explained that the way an animal behaves depends on its upbringing, and the movement of cells during foetal development means that a cloned mammal is never a perfect match.

SUPER DRONES

MEET THE ROBOTS EXPLORING ALIEN WORLDS, UNCOVERING ANCIENT SECRETS & HELPING HUMANITY

DIGGING NOW STARTS IN THE SKIES

The Indiana Drones pushing archaeology into a new era

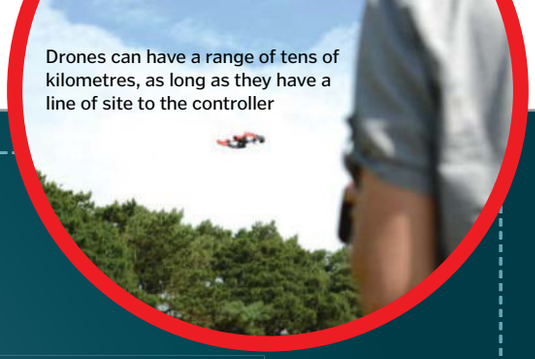
Archaeologists have used aerial photography to map dig sites for years. But where before they needed balloons, kites and airplanes to capture data, drones now make the process faster, cheaper and guarantee an image quality that couldn't be achieved before.

Drones can be piloted manually, or pre-programmed with a flight path over an area of archaeological interest, taking photos at regular intervals, and computer software can then piece these photos together to create an incredibly accurate topographical view of the area. The process is called photogrammetry, and it's changing the way archaeologists work.

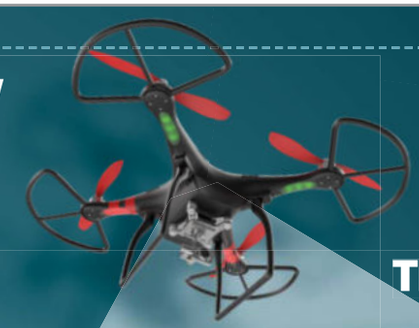
This detailed, three-dimensional map can be manipulated on-screen, allowing archaeologists to see tiny details just centimetres across without having even set foot near the site. Combined with satellite imagery, the scientists can extrapolate a great deal of data from these photos. Scholars can better understand how ancient communities were organised, and can even pick out rock carvings from the sky. Of course, the drones can only tell archaeologists so much – once they have acquired and analysed the data collected from the drones, they will still travel to the site and begin excavating the area. The benefit, however, is that they can more accurately choose the best places to dig before they get to the site, and make discoveries more quickly thanks to the information captured by the drone.

But drones aren't only used for picking excavation sites. They are also providing archaeologists with ongoing information that should help to curtail looting from these important historical sites. In remote areas of countries like Jordan, looting is a real problem, but it can be difficult for governments to track what is being taken and how much damage the looters are doing.

However, drones are able to survey an entire area in a matter of days, and at a resolution of one to two centimetres per pixel. This allows archaeologists to track the minute changes to the landscape, even when the looted area is larger than 50,000 square metres. Data is gathered over a number of years to determine just how much of a problem looting is in specific areas, which gives scholars and governments a better idea of the size of the problem.

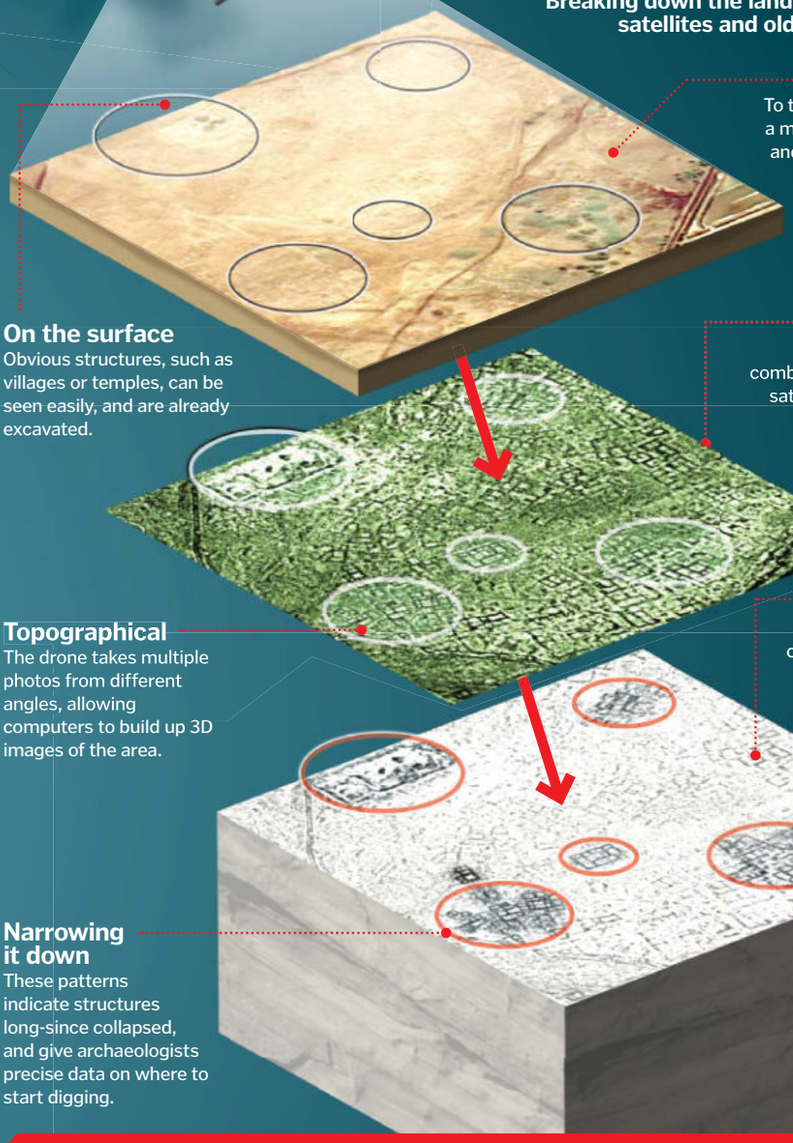


Drones can have a range of tens of kilometres, as long as they have a line of site to the controller



The photogrammetry process

Breaking down the landscape with drones, satellites and old-fashioned digging



Mud and rocks
To the naked eye, the site is a mound of mud and rocks, and from ground level it all looks the same.

On the surface
Obvious structures, such as villages or temples, can be seen easily, and are already excavated.

From the drone
A computer program combines images taken from satellites and drones into a high-resolution image.

Topographical
The drone takes multiple photos from different angles, allowing computers to build up 3D images of the area.

Combined
When these images are combined and studied, it is possible to see patterns that are only visible from the air.

Narrowing it down
These patterns indicate structures long-since collapsed, and give archaeologists precise data on where to start digging.

New discoveries in Petra

It seems strange that archaeologists are still finding new structures in a dig site as well-known as Petra, in Jordan, but thanks to the use of drones it is now possible for scholars to locate areas that previously remained hidden. In early 2016, archaeologists Sarah Parcak and Christopher Tuttle combined drone footage and satellite imagery to identify faint footprints of ancient buildings, which led to the discovery of a huge monument just 800 metres south of the ancient city's centre. This structure is roughly the size of two Olympic-sized swimming pools, but remained undiscovered for years.

Petra is already a huge archaeological wonder, but drones show there is more to find

DRONES IN CONSERVATION

Helping to save the natural world with flying machines

White rhino populations have increased in recent years, thanks to conservation work using drones

The white rhinoceros holds Near Threatened status due to devastatingly aggressive poaching, while the mountain gorilla and the orangutan are both classed as Endangered due to expansive deforestation and the broadening reach of humans. Without intervention, there is no doubt that these incredible creatures will be extinct before the end of the century. But scientists and conservationists are working hard to stop this terrible deterioration, and they're doing it with some pretty cool drone tech.

One of the biggest dangers to endangered animals in the modern day comes from poaching, which claims the lives of hundreds of white rhinos every year. However, while rangers and regular patrols can help in dissuading poachers from certain areas, they are often well-armed and unafraid to fire upon those hoping to protect the rhinos. This is where drones come in – if conservation researchers work in these areas there would be a real danger of coming into contact with the poachers, and their lives might well be at risk. By having drones collect data, movement patterns and numbers of animals, biologists are able to avoid many of these risks.

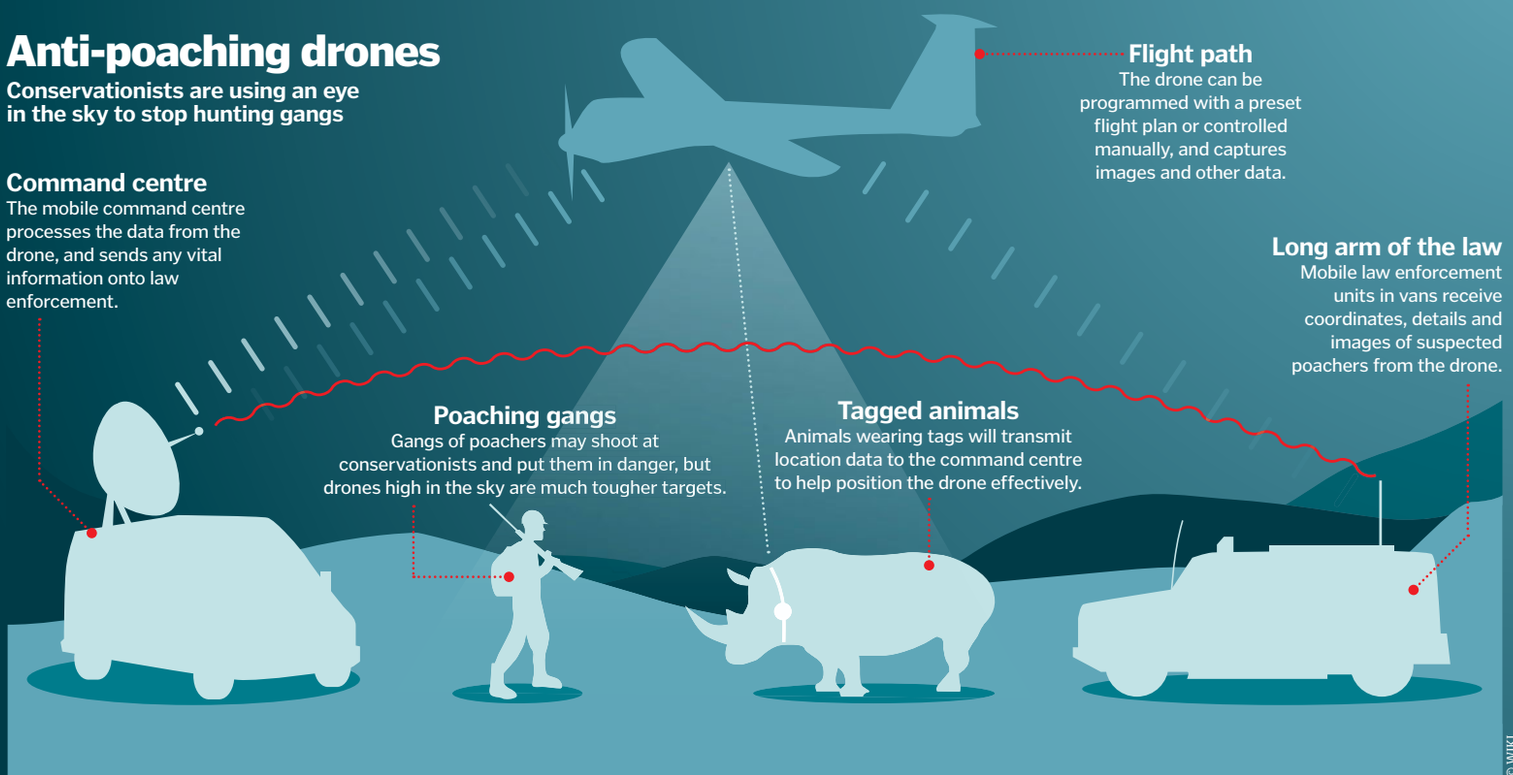
But drones aren't only used to collect information in dangerous areas – they can also be sent into the skies above difficult-to-reach areas to get data that would otherwise be tough to collect. Mountain gorillas and orangutans are usually found in dense jungle, and organising an expedition can be expensive, time-consuming, and require a great deal of bodies and planning. Instead, researches can send drones over the forest canopy to capture data about the habitat of the animals, and perhaps even capture high-quality images of an ape. This information can be incredibly valuable when it comes to an on-foot expedition, as researchers can get up-to-date information on the whereabouts of the animals as they move. In this situation, human-led surveys will still offer better results, but drones can play a huge part in the conservation process.

The downside currently is the cost, which can run into tens, if not thousands, of dollars. However, drone tech is still becoming a more feasible option in the fight against extinction.

Organisations like the WWF are using drones around the world to capture valuable data

Anti-poaching drones

Conservationists are using an eye in the sky to stop hunting gangs



Anti-drone technology

As drones become more common, limiting their movement is more important than ever

1 DroneDefender
This gun-like device uses radio pulses to disable drones within a 400-metre radius by interrupting their communications.

2 Drone on drone
Yes, drones can be used to capture drones. In this case, a large drone snags smaller flying machines in a hanging net.

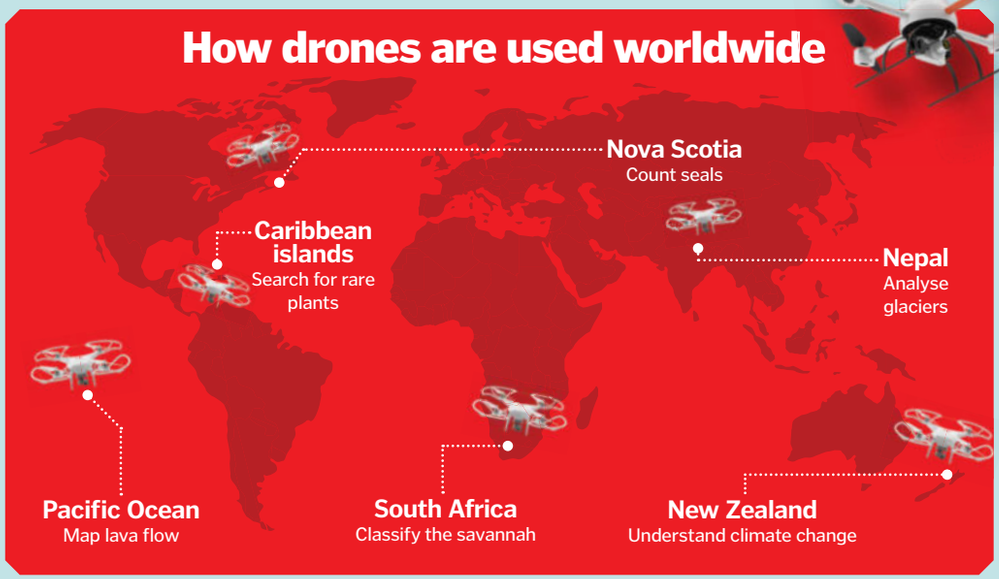
3 Boom!
Mobile weapon vehicles, armed with 50mm Bushmaster cannons, are being tested to eradicate drones in situations that may threaten soldiers.

4 Perimeter breached
Specially designed smart panels can be placed around an area, which send alerts via email if drones are detected.

5 Gun placements
For prominent buildings, such as the White House, permanent gun placements may help to keep people safe from drone attacks.

6 Smart prison guards
Prisons are now implementing anti-drone tech to prevent prisoners receiving contraband deliveries from outside.

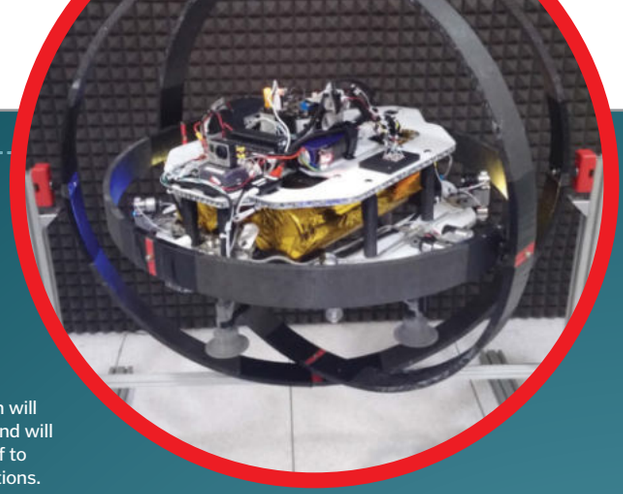
How drones are used worldwide



"Smart panels can send alerts via email if drones are detected"

STAR TREKKERS

How drones can be used in space exploration

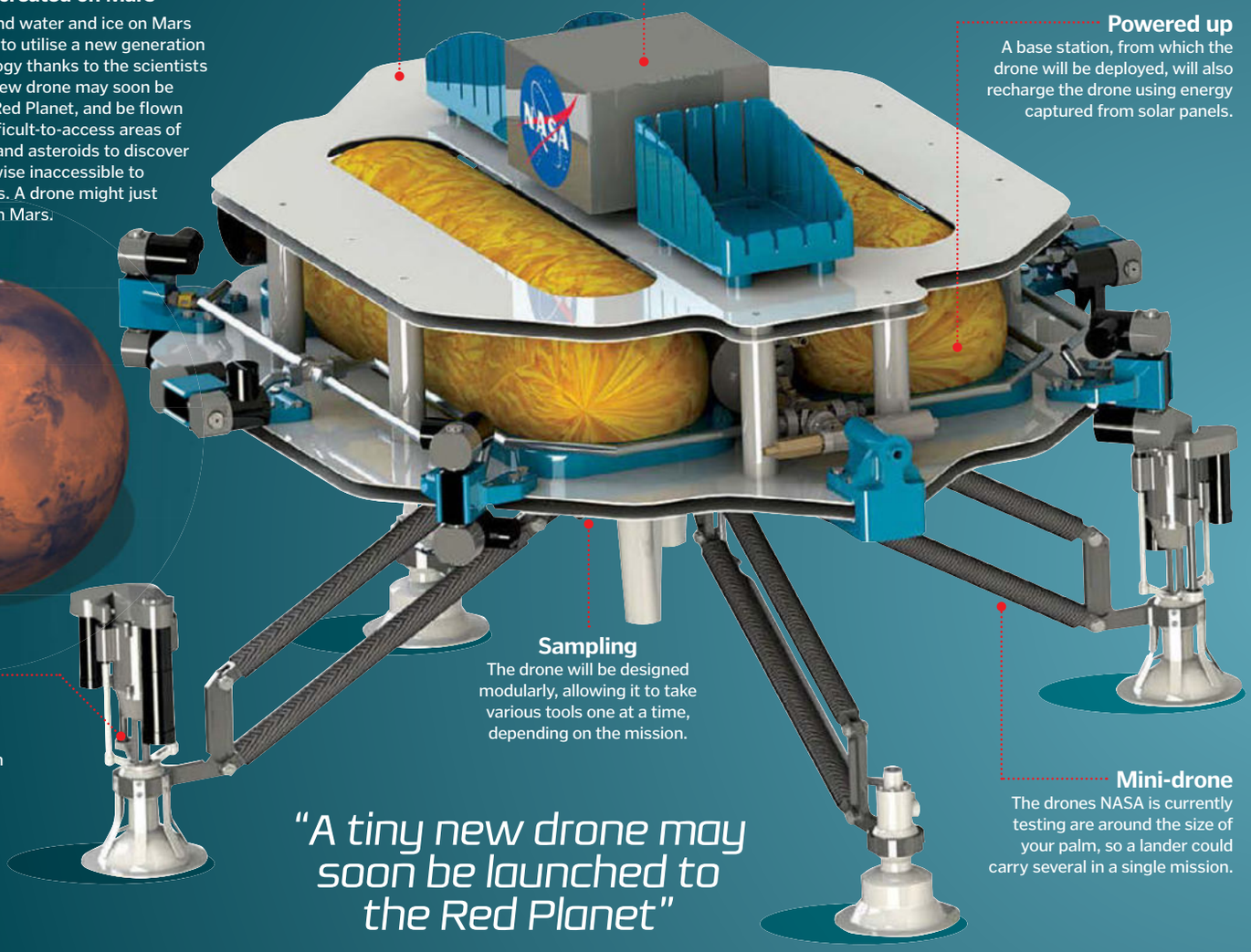


NASA's prototype drone is being tested in this gimbal to assess its low-gravity performance

Extreme Access Flyers

The next evolution of quadcopters will use fuels created on Mars

The mission to find water and ice on Mars will soon expand to utilise a new generation of drone technology thanks to the scientists at NASA. A tiny new drone may soon be launched to the Red Planet, and be flown into the most difficult-to-access areas of faraway planets and asteroids to discover resources otherwise inaccessible to land-based rovers. A drone might just discover water on Mars.



Cold-gas jets
Instead of rotors, jets will use oxygen or steam water vapour to handle the lifting and manoeuvring duties.

Navigation
The navigation system will recognise landscapes, and will be able to guide itself to pre-programmed locations.

Powered up
A base station, from which the drone will be deployed, will also recharge the drone using energy captured from solar panels.

No blades
The blades of a drone on Mars would have to be huge to gain lift in the thinner atmosphere.

Sampling
The drone will be designed modularly, allowing it to take various tools one at a time, depending on the mission.

Mini-drone
The drones NASA is currently testing are around the size of your palm, so a lander could carry several in a single mission.

"A tiny new drone may soon be launched to the Red Planet"

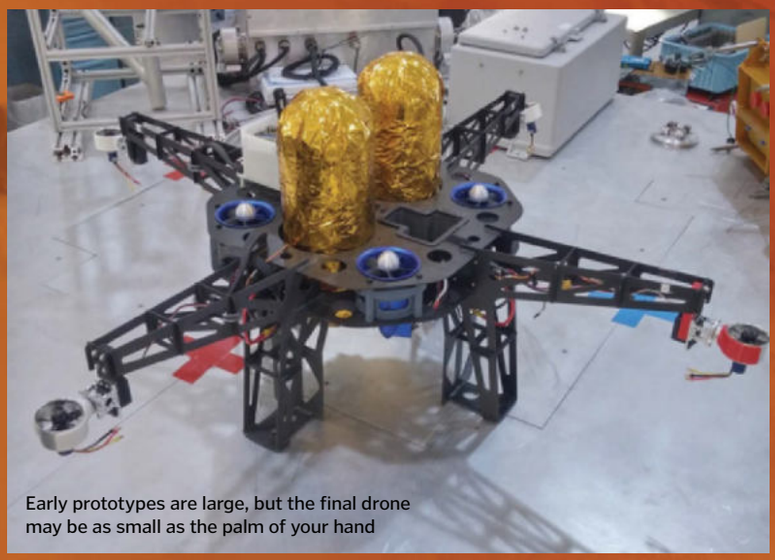
NASA's Prandtl-D

Drones are already used in space exploration – that is, if you count rovers and balloon-based scanners. But hundreds of thousands of miles away, drones may soon be used to scout new landscapes of planets using lightweight new designs like the Prandtl-D.

This aircraft, currently in development at NASA, may be the future of exploration thanks to a revolutionary design. The new wing is bell-shaped rather than a traditional elliptical shape, and the removal of a tail or flight control surfaces has dramatically reduced the craft's weight. Together, these features result in more than a 30 per cent increase in fuel economy.

The design began with the research of the early 20th-century aeronautical engineer Ludwig Prandtl, and also incorporates conclusions from several other engineers and aerodynamics pioneers. However, the craft's name, Prandtl-D, also stands for Preliminary Research Aerodynamic Design to Lower Drag – we wonder what Ludwig would think of that...

The revolutionary flat design takes inspiration from bird flight



Early prototypes are large, but the final drone may be as small as the palm of your hand

Exploring Saturn's moons

The drone craft that may soon search the surface, seas and skies of Titan

Titan is currently the only Earth-like world within our reach; with its liquid lakes, thick atmosphere and climate system, it's at the top of many astrophysicists' 'to visit' lists. Until now, the closest we've gotten is a pioneering but brief visit from the Huygens probe in 2005, but with the advancement of drone technology we may soon be exploring Saturn's moon from the land, sea and air.

Recharge station

Balloons could offer a mobile recharging station for smaller drones, which would deposit samples before taking flight again.

Picture perfect

Balloons, holding cameras, could fly over the surface of the moon, taking high-resolution images of the surface.

Distant world

Currently, scientists have only managed a brief landing on Titan, so we are sadly still years from a mission like this.

Back-up plan

Several drones could be taken in a single lander, so if one failed, another could be deployed.

Rotor-driven

Due to Titan's thick atmosphere, drones featuring rotors would fly far better than those using gas-powered flight.

Kraken Mare

Titan's largest known sea, known as Kraken Mare, is the primary target for any underwater drone.

Tough areas

Rotor-based drones could land in hard-to-reach areas, including at the top of inclines.

Instruments

The submarine will measure the lake's chemical composition, take images of the sea bed, and track currents and tides.

Into the unknown

The seas of Titan are composed of liquid hydrocarbons rather than water, so designing a suitable drone is difficult.

BioLite Camp Stove

The wood burner that can charge your phone while boiling the kettle

The main objective of the BioLite Camp Stove is not to generate electricity – it's to burn fuel more efficiently. Most small campfires can't draw in enough air to completely combust their fuel. This is why they produce smoke – tiny particles of carbon that are carried off by the rising hot air before they can be burned. Some wood burning stoves use clever convection tricks to pull more air, but they still smoke while the stove warms up.

The BioLite has an electrically powered fan that drives air into the bottom of the combustion chamber, which ensures hotter temperatures, less fuel use and a cleaner cooking environment. The electricity comes from a device called a thermoelectric generator. This uses the temperature difference between two sides of a special silicon wafer to generate an electrical charge. Once the fan is spinning fast enough, any excess electricity generated is diverted to a USB port for external charging.

From sticks to electrics

How the BioLite recycles waste heat to generate electricity

Photochromic lenses

How do glasses automatically get darker when outside?

Glasses with photochromic (or light-reactive) lenses appear clear when you wear them inside, but seem to transform into sunglasses as you step into natural light. This is thanks to dye molecules in the surface of the lens called naphthopyrans, which change their structure when bombarded with ultraviolet (UV) light. As they change, they absorb more light, making them appear tinted.

When you step indoors again, the level of UV light hitting the lenses falls, because window glass blocks these rays. The dye molecules will then revert to the transparent form within around 15 minutes.

Photochromic lenses are a great way for wearers of prescription glasses to avoid the need for separate sunglasses, but they do have disadvantages. The reaction that turns the glasses clear actually happens constantly, but in UV light a darkening reaction dominates and the lenses appear dark. However, the clearing reaction is faster at high temperatures, so on hot days, the lenses don't darken fully. On cold days, they can take half an hour to lighten indoors.

Photochromic lenses mean glasses wearers don't need to buy separate sunglasses

Is Li-Fi the future?

Wireless technology that makes Wi-Fi look like smoke signals

Li-Fi is like Wi-Fi except it uses visible light to send and receive data, instead of radio waves. Light and radio waves are just different frequency ranges in the same electromagnetic spectrum, but using light waves has some big advantages. First, the visible light range of the spectrum is 10,000 times bigger than the entire radio spectrum, and Wi-Fi is restricted to a tiny slice of that. So Li-Fi can fit more data into its signal. Speeds of up to one gigabit per second have been reached in real-world tests, with greater speeds achieved in the lab. Li-Fi is cheap too; it uses simple LEDs to broadcast data by flickering them on and off so rapidly that, to the human eye, they don't even appear to be lit.

The range of Li-Fi is much shorter than Wi-Fi, as it won't travel through walls or floors, but this improves security because it is much harder for a hacker to eavesdrop on your signal. Homes and offices can be fitted with a cheap repeater in every light socket, and the signal works after bouncing off walls and furniture, so it doesn't need a direct line of sight.

Li-Fi won't replace mobile phone technologies like 4G, or the microwave wireless links used to connect buildings, but its speed, low cost and security could make ordinary Wi-Fi redundant.

Li-Fi is a super-speedy alternative to Wi-Fi

Wired for light

Li-Fi is cheap enough to connect everything in the home or office

Internet connection
Ceiling-mounted lights are wired to the office Ethernet to connect users to the internet.

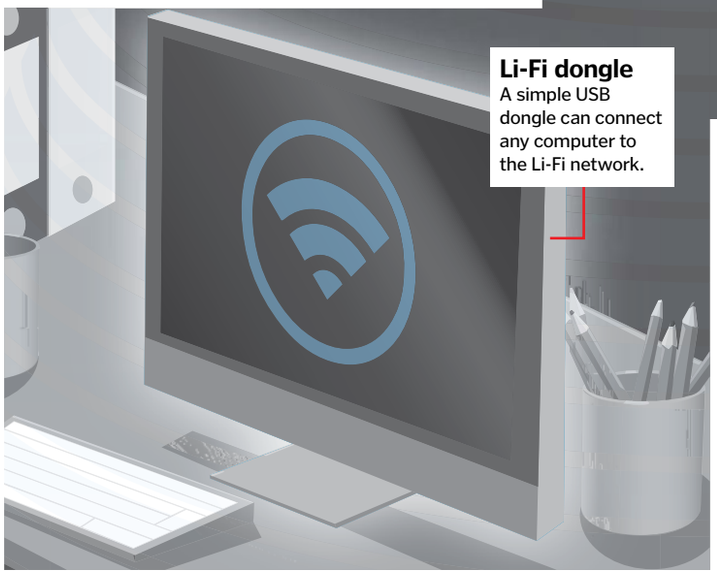
Access points
Every light fitting can be converted to an access point, simply by replacing the bulb with a Li-Fi-enabled one.

One-way traffic
Some devices only need to receive data, such as a clock that uses the internet to stay synchronised.

Privacy screen
Li-Fi won't pass through walls or doors, which makes it more secure than Wi-Fi.

Internet of things
A battery-powered sensor stuck in a pot plant could send an instant message asking to be watered.

Invisible data
Signals are broadcast as a flickering in the background lighting, far too faint for humans to see.



Li-Fi dongle
A simple USB dongle can connect any computer to the Li-Fi network.

Is the technology really new?

Invisible light pulses have been used to send digital data for at least 35 years. In the 2000s many computer devices used the IrDA infrared standard, but IrDA needs line of sight to work. Infrared occupies a smaller slice of the electromagnetic spectrum than the visible light range used by Li-Fi. That means it's about 250 times slower than Li-Fi. This technology isn't a revolution; it's an evolution that combines the omnidirectional advantage of Bluetooth with the low cost and security benefits of IrDA. It does so at a speed that leaves them both – and Wi-Fi – standing.

Your TV remote is the ancestor to the modern Li-Fi transceiver

The mechanics of vertical wind tunnels

How to free-fall without ever hitting the ground

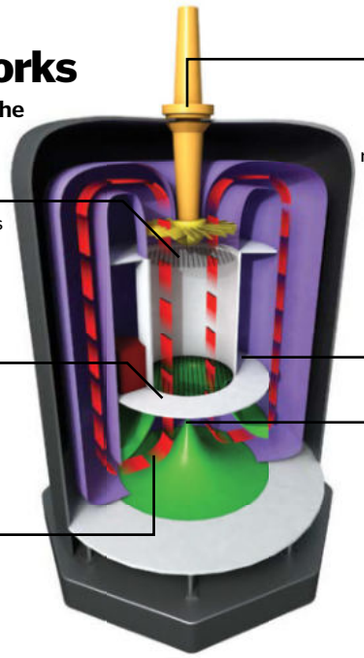
Vertical wind tunnels were originally developed for aeronautical testing, but they are now far more popular with people looking to experience skydiving (without the scenery or terrifying altitudes, of course). A vertical wind tunnel works by using a diesel or electric motor to power a giant fan that spins at 990 revolutions per minute to generate winds of 190 kilometres per hour – the average speed at which a person free-falls.

This air is then directed through the top of the wind tunnel and circulated around the outside and back through an inlet. The air's rapid movement creates friction and therefore heat, so an air-conditioning system cools it down to a comfortable temperature for the flier. As long as the flow of air continues at this precise speed, the flier will hover in a suspended state. This is because the air is travelling at the same speed as their terminal velocity (the point where the forces due to gravity and air resistance are equal).

However, indoor skydivers can move about by making tiny movements with their limbs. They don't need to worry about throwing caution to wind, however, as a steel mesh protects them from the giant spinning blades below.

How it works

The tech behind the indoor skydiving experience



Motor
A powerful diesel or electric motor drives the fan blades at 990 revolutions per minute.

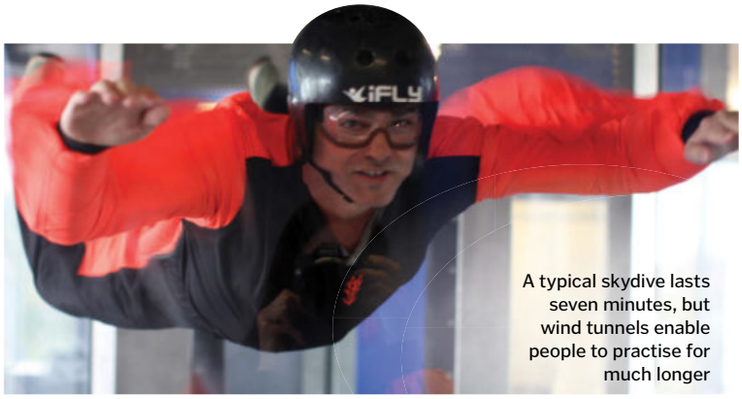
Screen
A steel mesh prevents the fliers from being blown into the fan.

Spectators
Windows in the side allow spectators to view the fliers.

Padding
The walls are padded and the floor is made of trampoline netting.

Inlet
The inlet narrows to force the airstream to accelerate to 190km/h or more.

Circulation
Air is ventilated around the outside of the wind tunnel, back to the bottom.



A typical skydive lasts seven minutes, but wind tunnels enable people to practise for much longer

Paper shredders

How a series of rotating knives can protect personal data

A strip-cut shredder uses a powerful electric motor to drive a series of disc blades four millimetres apart, slicing a piece of A4 into 53 strips. That's fewer pieces than you could manage with your hands if you tore a sheet in half then in half again, seven times. But long, thin strips are harder to reassemble, as they tear and tangle, and the straight edges make it harder to complete the puzzle. Despite this, strip-cut documents have been reassembled in the past – the documents shredded by the CIA at the start of the Iranian Hostage Crisis in 1979 were eventually reconstructed by hand over several years. This is why modern paper shredders also have blades running horizontally along the roller, to cut each strip into short lengths. Good home office shredders can chop a sheet into sections four millimetres by 30 millimetres. But this is just Level 3 in the European 'DIN' shredding standards. The highest standard, Level 6, requires shredders to chop fragments over 30 times smaller! And some shredders can reduce paper almost to dust.

The US Government has developed impressive computer software that automatically reconstructs the information on shredded documents

Capturing a digital image

How a camera converts light into photo files on a memory card

With the simple click of a button, a digital camera turns light into data. This process starts with the image sensor, which is a silicon chip known as a CCD or CMOS. When light enters the camera lens, it is focused onto the sensor and dislodges some of the electrons in a tiny area of the silicon (known as a pixel), which creates an electrical charge. The brighter the light in that part of the image, the stronger the electrical charge that is created at that spot on the sensor.

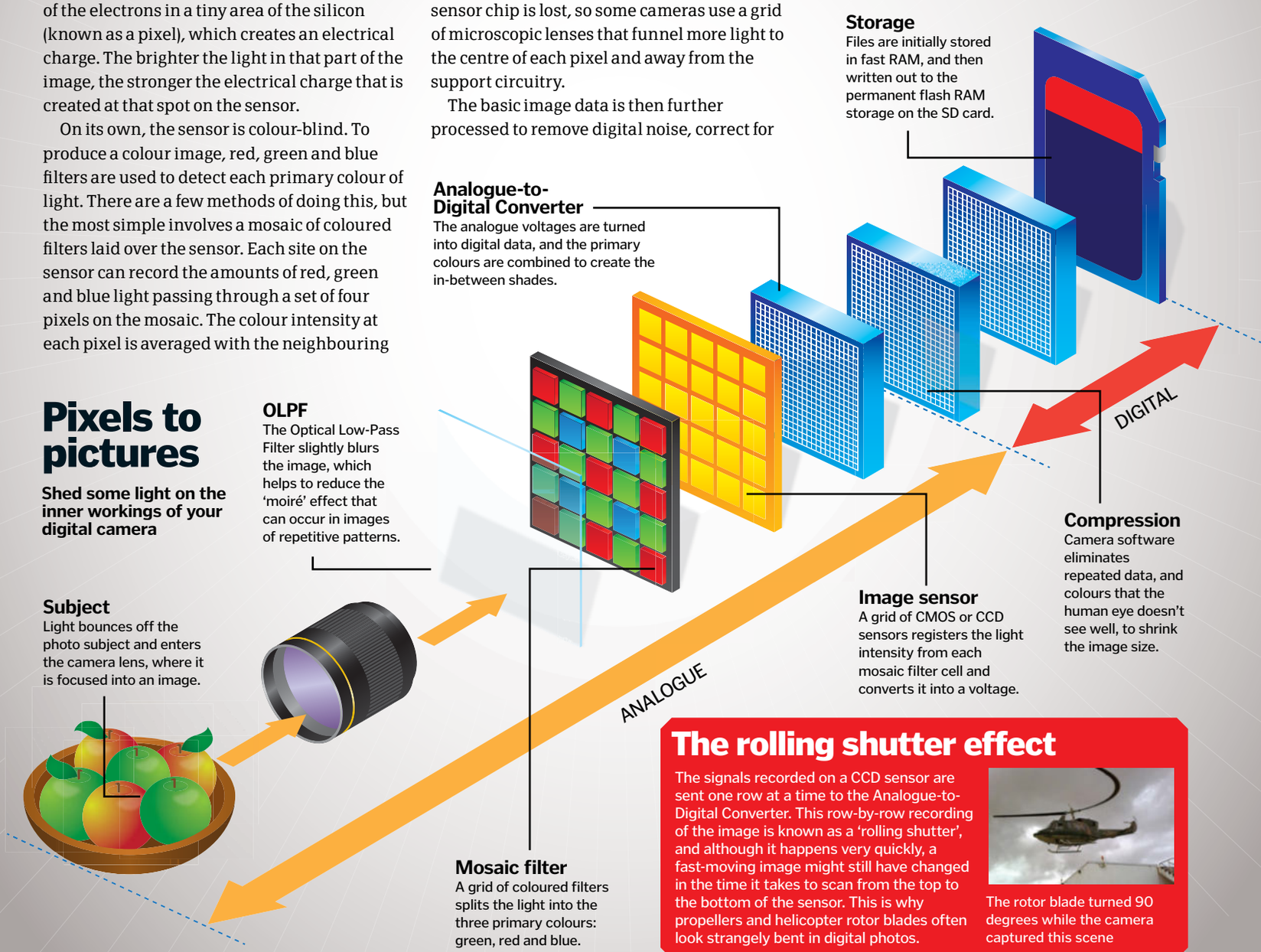
On its own, the sensor is colour-blind. To produce a colour image, red, green and blue filters are used to detect each primary colour of light. There are a few methods of doing this, but the most simple involves a mosaic of coloured filters laid over the sensor. Each site on the sensor can record the amounts of red, green and blue light passing through a set of four pixels on the mosaic. The colour intensity at each pixel is averaged with the neighbouring pixels to recreate the true colours of the image using special algorithms that run on the camera's Central Processing Unit.

Each pixel also needs some circuitry around it to allow the electrical charges to be amplified and read. The light that falls on this part of the sensor chip is lost, so some cameras use a grid of microscopic lenses that funnel more light to the centre of each pixel and away from the support circuitry.

The basic image data is then further processed to remove digital noise, correct for shadows cast by the camera lenses, and eliminate the flicker caused by artificial lighting. This data is then assembled into a format that can be read by other computers and written to the SD card as a JPEG file.

Pixels to pictures

Shed some light on the inner workings of your digital camera



The rolling shutter effect

The signals recorded on a CCD sensor are sent one row at a time to the Analogue-to-Digital Converter. This row-by-row recording of the image is known as a 'rolling shutter', and although it happens very quickly, a fast-moving image might still have changed in the time it takes to scan from the top to the bottom of the sensor. This is why propellers and helicopter rotor blades often look strangely bent in digital photos.

The rotor blade turned 90 degrees while the camera captured this scene

The hidden science of cities

Discover the technologies that run the world's urban environments

How do skyscrapers stay up?

The Burj Khalifa is the tallest building in the world, stretching 828 metres into the Dubai sky. The secret to its height is its core, an 11-metre-wide hexagonal tube of reinforced concrete. The Burj also borrows an idea from Gothic cathedrals – it uses side walls called buttresses to help support the main structure. The resulting buttressed core acts as a stiff supportive spine that runs from the ground floor to the very top of the building. This design allows it to get taller without the steel frame approach used in the Empire State Building.

Why do electricity lines buzz?

Power lines transmit electricity at up to 400,000 volts. The electric field 'charges up' the air that surrounds each cable. It rips electrons from nitrogen molecules, which releases energy in the form of sound and sometimes light.

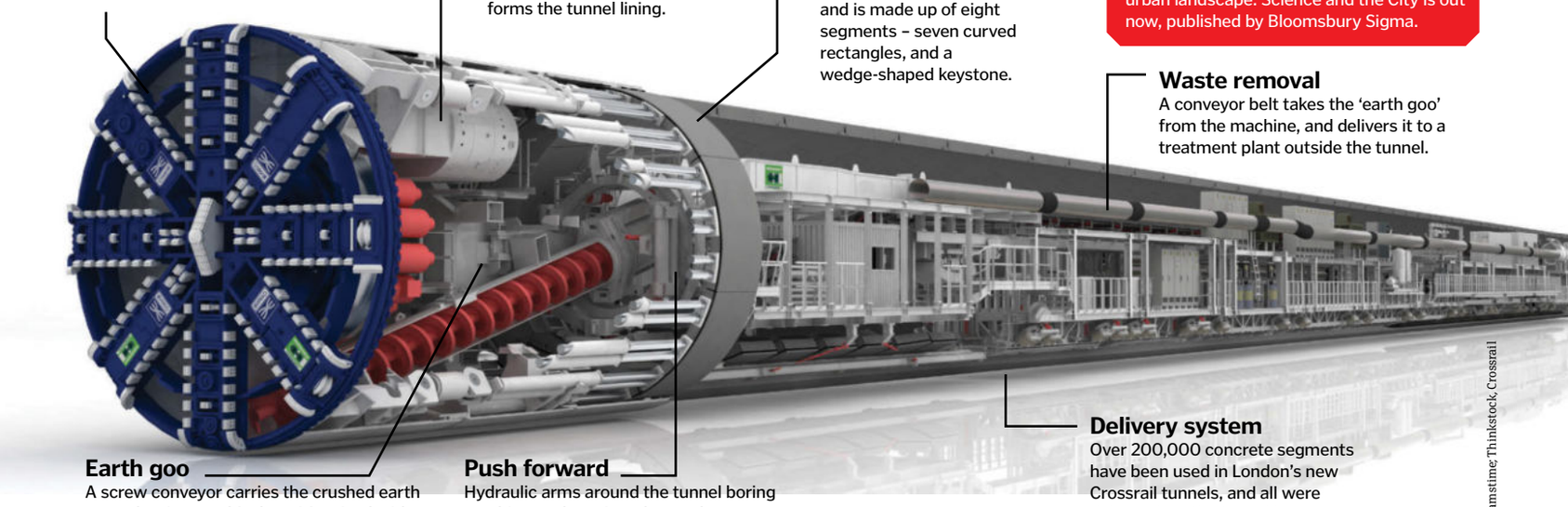
Because power lines use alternating current, which flips direction 50 or 60 times every second, we can't hear every individual electron-ripping event – instead we hear a constant buzz. Water in the air increases its electrical conductivity, so this sound tends to be much louder if it is raining, snowing or foggy.

How clean is my tap water?

Water goes through lots of cleaning processes before it comes out the tap. First, large contaminants such as leaves are removed, and a chemical is added so smaller contaminants form clumps or 'flocs'. The water is mixed to cause the flocs to stick together. The now-heavy flocs drop to the bottom of the tank and are pumped out. The water is then filtered through layers of sand to remove any remaining particles, while bacteria in the water is removed using ozone or chlorine. These treatments produce tap water that is as clean as bottled water.

How are tunnels dug?

Today's tunnels are made with huge mechanical earthworms called tunnel boring machines



Rock-eating
The circular cutter head is covered in many hard 'teeth' made from tungsten carbide. It rotates to loosen the earth.

Concrete ring
A rotating, hydraulic arm installs curved pieces of concrete to create a ring that forms the tunnel lining.

Tunnel support
Each ring weighs 22 tons and is made up of eight segments – seven curved rectangles, and a wedge-shaped keystone.

Waste removal
A conveyor belt takes the 'earth goo' from the machine, and delivers it to a treatment plant outside the tunnel.

Earth goo
A screw conveyor carries the crushed earth towards a 'stomach' where it's mixed with other compounds to make it gooey.

Push forward
Hydraulic arms around the tunnel boring machine push against the newly installed ring to move itself forward.

Delivery system
Over 200,000 concrete segments have been used in London's new Crossrail tunnels, and all were delivered via the tunnel boring machine's feeder.

Why do tall buildings use revolving doors?

Revolving doors regulate temperatures. In winter, heated air rises, leaving a vacuum on the lower floors. With swinging doors, air is sucked in to fill the vacuum, creating a gust of wind. In summer, cool, air-conditioned air sinks, and rushes out of a swinging door. But a revolving door is always 'closed' to the outside, preventing air from being sucked in or pushed out.

Can traffic lights 'see' cars?

Standard traffic lights use a magnetic sensor buried in the road to detect vehicles, but new traffic lights being trialled in London really can 'see' pedestrians and cyclists. They use a combination of radar and thermal systems, along with low-resolution cameras to detect the presence of pedestrians at crossings, and cyclists at key intersections in the city.

What powers London's buses?

The majority of the fleet's 9,300 buses run on standard petrol or diesel engines, but 1,500 of them use hybrid engines, powered by an electric motor alongside a fuel engine. London's new all-electric double-deckers can travel 290 kilometres on one charge. Eight buses run on hydrogen gas, combined with oxygen in their engine to produce electricity.

How do traffic jams form?

Many traffic jams are caused by too many cars on not enough road. 'Phantom jams' form because drivers struggle to maintain a constant speed. If a person drives too fast, they might hit the brakes to correct their speed. The person behind them then brakes more, and so on. This effect grows and ripples back to other cars, until traffic grinds to a halt.

MEET THE EXPERT

Laurie Winkless is a science writer with a background in physics and materials research. In her new book, she takes readers on a scientific journey through the urban landscape. Science and the City is out now, published by Bloomsbury Sigma.

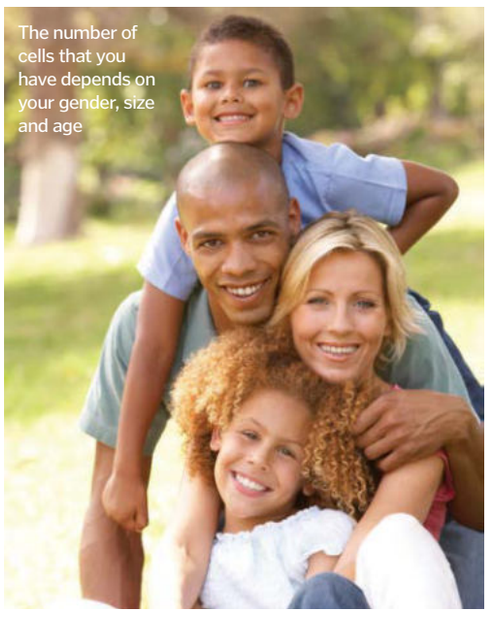
How many cells do you have?

Estimating the number of your body's building blocks is not as straightforward as it seems

By the most recent estimates, the average human is made up of approximately 37.2 trillion cells. To put that unthinkably large number into some perspective, consider that there are 'only' 100 billion stars in the entire galaxy. Even if it were feasible to painstakingly isolate every single cell, simply counting to 37.2 trillion would take you over a million years. So how exactly did scientists reach this mind-boggling number?

A team of researchers from Italy, Greece and Spain used a systematic approach: they considered different cell types individually. They gathered as much information as possible from scientific research papers to find the total number of cells in the various organs and systems of an average person, and added up these results to get the titanic total of 37.2 trillion.

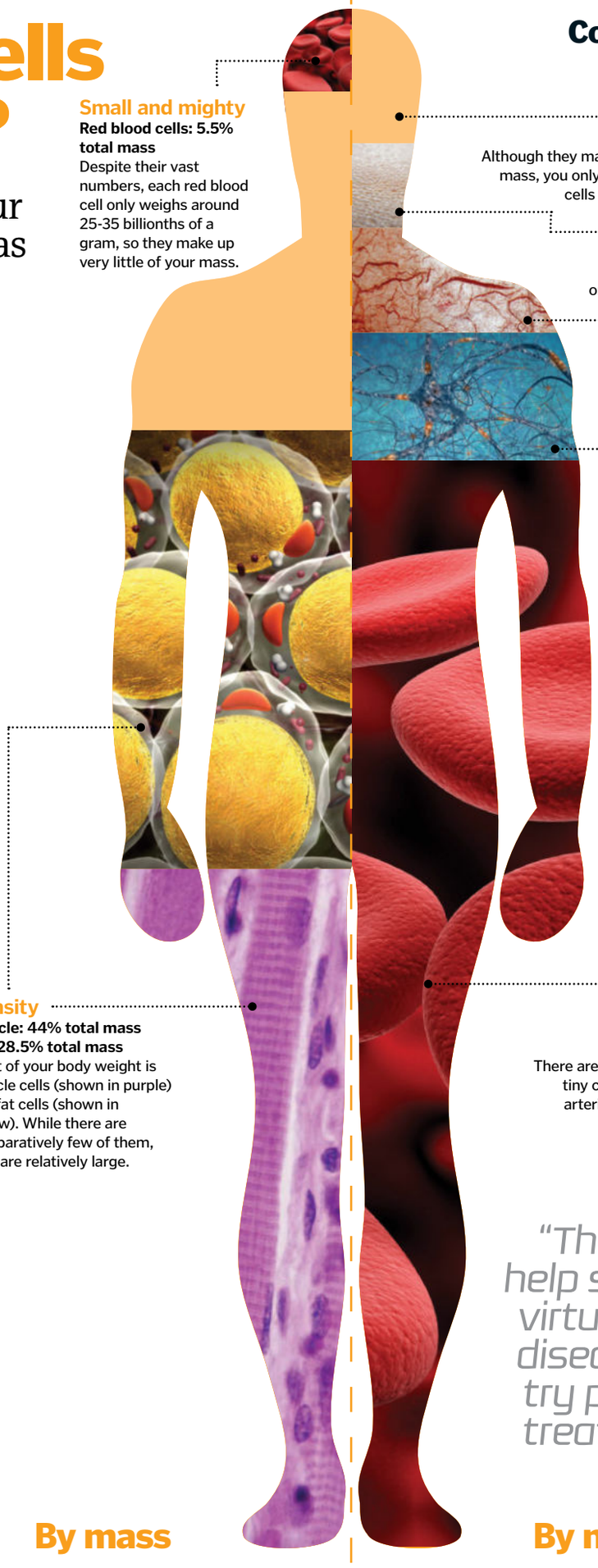
Counting the number of cells in a human being may seem like a pointless exercise, but this information is valuable for a range of applications. For example, accurate cell counts can improve the precision of computer models of the body. This could help scientists to virtually map diseases and try out potential treatments. Comparing a patient's cell count of a particular organ to that of the average human may also help doctors to diagnose diseases.



The number of cells that you have depends on your gender, size and age

Counting cells

See how your cell types stack up



Small and mighty

Red blood cells: 5.5% total mass

Despite their vast numbers, each red blood cell only weighs around 25-35 billionths of a gram, so they make up very little of your mass.

And the rest

8.7% total cells

Although they make up the majority of your mass, you only have around 50 billion fat cells and 17 billion muscle cells.

Skin cells

5.5% total cells

Your skin is your largest organ, composed of around 2 trillion cells.

Blood and lymph vessels

6.8% total cells

Approximately 2.5 trillion endothelial cells line your body's vast network of veins, arteries and lymphatic vessels.

Nervous system

8.3% total cells

You have roughly 100 billion neurons, insulated and supported by 3 trillion glial cells.

Density

Muscle: 44% total mass

Fat: 28.5% total mass

Most of your body weight is muscle cells (shown in purple) and fat cells (shown in yellow). While there are comparatively few of them, they are relatively large.

Red blood cells

70.7% total cells

There are around 26 trillion of these tiny cells coursing through your arteries and veins, transporting oxygen around your body.

"This could help scientists virtually map diseases and try potential treatments"

By mass **By numbers**

© National Space Centre

Family days out

If you fancy an exciting and educational day out this summer, then why not take a trip to one of our recommended attractions? Whether you want to explore the cosmos, get hands-on with history, immerse yourself in theatre or take a supersonic thrill ride, you'll find there's fun for all the family at each of our top four picks…

The National Space Centre, Leicester

Discover the wonders of the universe

www.spacecentre.co.uk

The award-winning National Space Centre is an out-of-this-world experience for the whole family. With six interactive galleries, the UK's largest planetarium, a world-unique 3D SIM ride and an iconic 42m high Rocket Tower, there really is something for everybody to enjoy.

Add to this on-site parking, café, shop and all the facilities you would expect from a world-class attraction. An all-weather day out in the heart of the UK, just follow the rocket signs from the M1 and M69.

In 2016 the Centre will be hosting many special weekends. School holiday periods are always exciting, as the Centre adds lots of workshops and talks into the mix, so advanced booking is advised. Don't forget that if you book in advance you will beat the queues, be able to upgrade to a free Annual Pass and there are no booking fees!

DIG, York

A hands-on archaeological adventure

www.digyork.com

"***One of the best family days out. No other experience gets you as close to the excitement of archaeological discovery.***" *The One Show*'s Dan Snow.

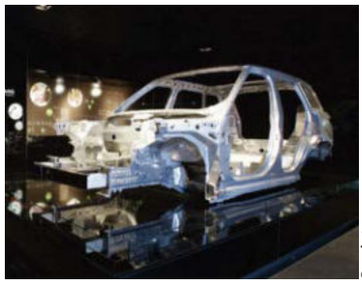
DIG is a hands-on archaeological adventure giving kids the chance to become trainee 'diggers' and discover the most exciting artefacts from 2,000 years of York's history! With four special indoor excavation pits, all based on real-life digs in the city and filled with replica Roman, Viking, medieval and Victorian finds, children can grab a trowel and explore how people lived in these times.

Dig, delve and discover today!

Coventry Transport Museum

Explore amazing vehicles

www.transport-museum.com



© mubsta.com

Discover the heart of Britain's transport industry, the people behind the technology and the innovation that made Coventry an industrial powerhouse for over 120 years. Explore stunning new galleries and uncover the role that Coventry played in the design and manufacture of transport through the ages. From the Rover Safety bicycle to the fastest car in the world, the Thrust SSC, Coventry Transport Museum will take you on a journey through design and innovation. Delve into a world of manufacture, design and social history and experience record-breaking speed on the Thrust SSC Landspeed record 4D simulator. There's sure to be something for everyone!

Shakespeare's Globe, London

Catch an incredible show at a legendary theatre

www.shakespearesglobe.com/946

Join the London premiere of Kneehigh's triumphant family show, adapted from the bestselling novel by Michael Morpurgo (author of *War Horse* and *Running Wild*).

It's 1944 and, in Devon, 12-year-old Lily is made to leave her home, her village and her beloved cat, Tips, so that American soldiers can practice the DD landings. Fusing music, puppetry and foolishness to tell a tale of love, prejudice and war, *946: The Amazing Story of Adolphus Tips* reveals secrets the US and British governments tried to keep quiet.

946: The Amazing Story of Adolphus Tips runs from 11 August to 11 September 2016. Book your tickets now!

© Steve Tanner

Coloured fire

When different elements burn, they create a whole rainbow of colours

Dropping elements into a flame adds an instant energy boost, and it can have dramatic effects. Depending on the element you use, the flame changes colour, and it's all down to electrons. These are found around the nucleus of every atom, and they exist in distinct numbers and patterns depending on the element.

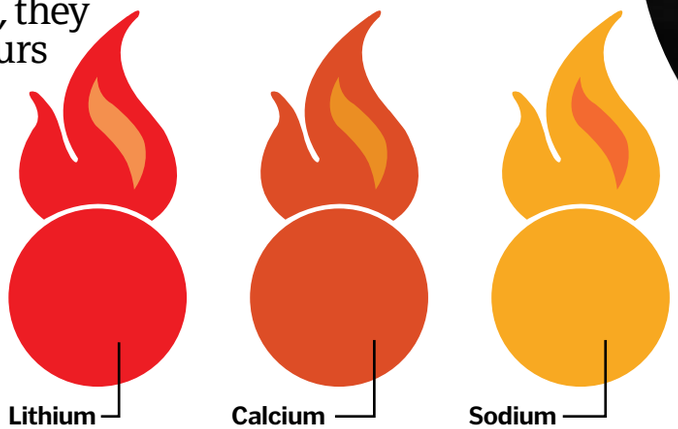
At a normal energy level, these electrons tend to be found in predictable locations, known as orbitals, but when energy is added, their positions shift. The electrons furthest away from the nucleus can move upwards into higher orbitals, becoming 'excited'. When they drop back down to their original positions, they release the energy again, in the form of a photon of light.

The colour of the flame is determined by how far the electrons have jumped and then dropped back; this releases a specific amount of energy, producing a distinctive wavelength of light. Different elements produce different colours depending on how many electrons they have, and where their orbitals sit.

This property can be used by chemists to identify unknown elements in compounds and mixtures. It doesn't happen for all elements, but many metals produce distinctive flame colours, instantly revealing their presence.

Flame tests

Flames can be used to identify metals, and to make colourful fireworks



Lithium
Lithium makes a red light, used in firework displays.

Calcium
Calcium produces a red-orange glow when exposed to a flame.

Sodium
Sodium makes a yellow-orange light, commonly seen in old street lamps.

Potassium
Potassium has a characteristic purple or lilac flame.

Boron
Boron derives from the Arabic for white, but it burns green.

Copper
A green-blue flame test result indicates the presence of copper.

Caesium
A caesium flame burns with a variable blue-purple colour.

Can you work out which metals were used to make these fireworks?

Singing glasses

The slippery science behind creating a wine glass symphony

This popular party trick is based on the same physics that underpins all musical instruments, and it's all down to vibrations. When you run a dry finger around the rim of a glass, it generates friction. Electromagnetic attraction between the molecules in your skin and the molecules in the glass resist the movement of your hand, causing it to stick.

A wet finger will slip more easily across the surface, but it still encounters a small amount of friction, and it's this resistant force that causes the glass to vibrate. Each material vibrates at a slightly different frequency, and for wine glasses, this sits right in the middle of the frequency that the ear can detect as sound.

The pitch of the note can be altered by changing the amount of water in the glass. Adding more water slows the vibrations and produces a lower sound. If you take your hand away when a glass starts to vibrate, it will continue to sing for a few seconds, and if you line up a whole row of glasses with different water levels, you can even play more complex tunes.

Wine glasses can be used to create a DIY instrument known as a 'glass harp'

Face the fats

Discover the different types of fat in your food

Fat has a bad reputation. Eating too much has been linked to weight gain, high cholesterol and heart disease, and supermarket packaging nudges us towards the low-fat or fat-free options. But some fat is absolutely essential for survival.

A membrane made from fats surrounds every cell in the human body. Fat insulates our nerve cells, a bit like the plastic coverings on electrical wires. It provides warmth, and it cushions the soles of our feet and the palms of our hands.

Dietary fat also helps us to absorb vitamins A, D and E, which do not dissolve in water. Fats are one of the three macronutrients, the major food types that provide our bodies with energy. The others, carbohydrates and proteins, each provide four kilocalories of energy per gram, but fats pack a whopping nine kilocalories, making them our densest energy source.

The recommended intake of fat per day is around 95 grams for a man, and 70 grams for a woman, but not all fats have the same effect on our health. While they all provide the same amount of energy, it's true that some fats are better for our bodies than others.

OMEGA-3 FATTY ACIDS

This group of polyunsaturated fats are mainly found in oily fish, but also in plant foods such as nuts and seeds. They can't be made by the body, but are important for growth and development, and are thought to have a protective effect on the circulation. Omega-3 fatty acids are found in high concentrations in the brain, and getting enough of these nutrients during childhood is thought to be important for nerve development.

OMEGA-6 FATTY ACIDS

Like omega-3 fatty acids, our bodies cannot make omega-6. These fatty acids are found in meat and vegetable oils, and are often consumed more readily than omega-3. In the US, for example, a typical diet contains over ten times more omega-6 than omega-3. While both are essential for health, researchers think that getting a balance could be important in maintaining optimal health.

SATURATED FATS

The main fats in our diet come in the form of fatty acids. These molecules are made from chains of carbon atoms, with a carboxylic acid group at one end. Each carbon in the chain can bind to up to two hydrogen atoms. If all of the carbon atoms are bonded to the maximum number of hydrogen atoms, the fatty acids are 'saturated'. These fats tend to be solid at room temperature, because the molecules are straight and pack tightly together. Saturated fats come mainly from animals, but can also be found in plant oils like palm and coconut. Eating them has been linked with high cholesterol, so limiting your intake is recommended.

MONOUNSATURATED FATS

Unsaturated fats have gaps in terms of hydrogen atoms bound to their carbon chains. At least two carbon atoms are joined together by a double bond. This creates kinks in the long chains, making it harder for the molecules to pack together. So the fats tend to be liquid at room temperature. Monounsaturated fats have just one double bond. Foods tend to contain a mixture of saturated and unsaturated fatty acids, but the proportions of unsaturated fats are higher in plant foods like olive oil and avocados. They help to lower cholesterol levels in the blood.

POLYUNSATURATED FATS

Polyunsaturated fats have more than one double bond in their carbon chain, making several kinks. They are found in plant oils, as well as oily fish like mackerel, sardines and salmon. They have been shown to help lower blood cholesterol, and they also have an important role in our cells. Every cell in the body is surrounded by a membrane, which contains fatty acid chains. Polyunsaturated fats are very important in maintaining the fluidity of these membranes, helping to keep them flexible. While we can make many of the fats that our bodies need, some polyunsaturated fats are known as 'essential', meaning that we can only get them from our diets.

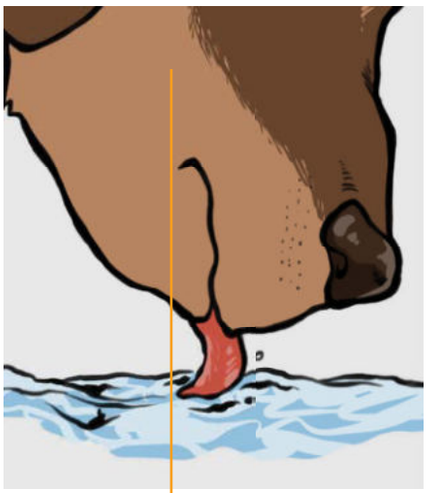
TRANS FATS

These fats aren't found in high quantities in nature, and are more commonly made during food manufacturing. The process involves passing hydrogen through unsaturated fats to fill up gaps on the carbon chains. This helps to straighten out molecules, making them behave more like saturated fats. They are solid at room temperature, and have a longer shelf life than their unprocessed counterparts. They are in products like margarine, and in processed foods like cake and biscuits, and are worse than saturated fats for raising blood cholesterol.

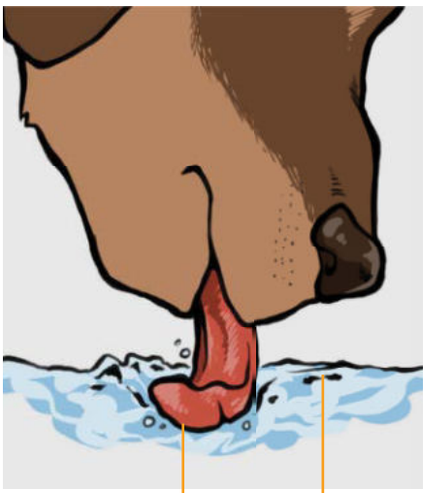
Dogs use their tongues like scoops to draw water up from the surface

How do dogs drink?

Our clever canine companions use fluid dynamics to quench a thirst

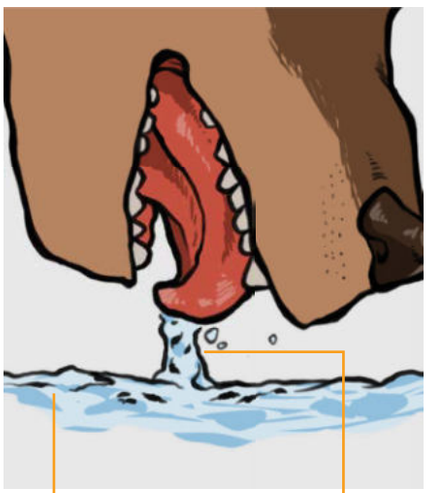


1 Cheeks
Dogs are unable to form a proper seal with their cheeks, so they can't suck up water to drink like we do.



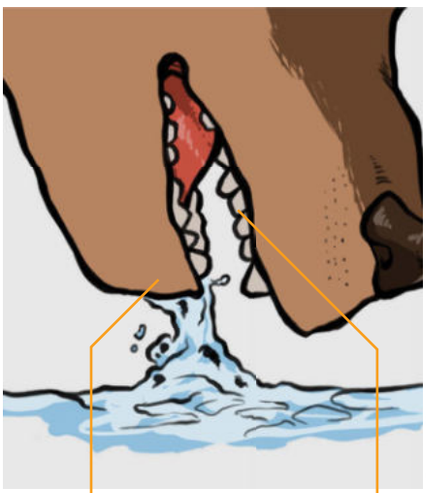
2 Scoop
Using the tip of their tongue like a ladle, dogs scoop up water towards their mouth.

3 Mucky pup
Their tongues don't actually work very well as a scoop. Most of the water falls off as it's retracted.



4 Rapid retraction
Withdrawing the tongue creates a considerable amount of acceleration, as much as five times that of gravity.

5 Water column
This quick, upward motion creates inertia, so the water continues to rise against gravity.



6 Snap shut
Before gravity causes the water column to collapse, the dog closes its mouth around it.

7 Swallow
As the dog scoops up a fresh batch of water, the previous lot is forced to the back of its mouth to be swallowed.

What is a spot?

Find out why we get pimples and what we can do about them

In the Western world, acne affects up to 90% of adolescents

Pimples, spots, zits – they can be the bane of our lives. But these small skin lesions affect about 80 per cent of people aged 11 to 30. They occur when hair follicles – the shaft that hair grows out of in the skin – become blocked and infected. They normally occur on the face, back, chest and shoulders.

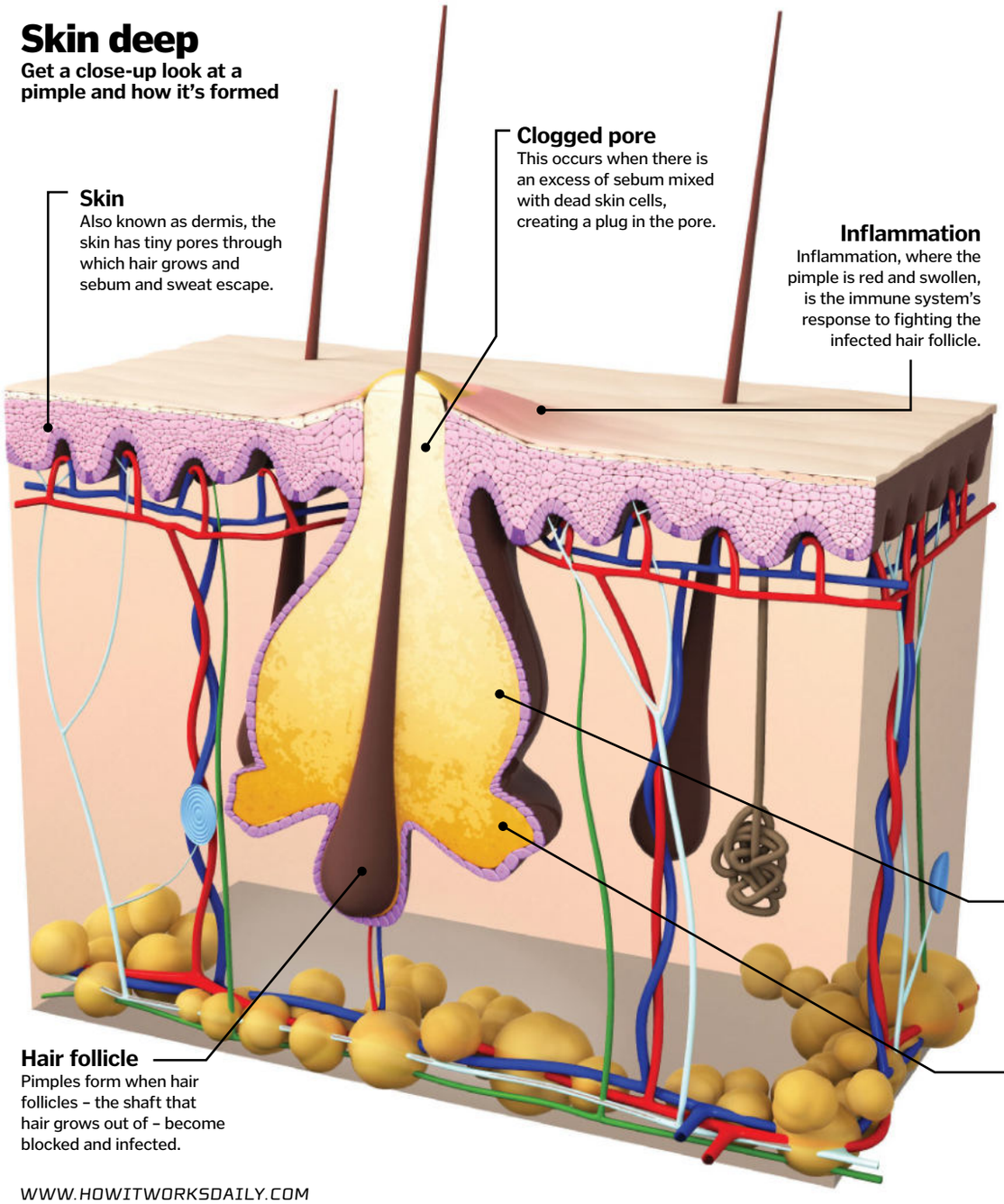
Attached to these follicles are sebaceous glands, which continually produce an oily substance called sebum. This helps to lubricate the skin and hair, but if too much is produced it can cause acne. The sebum mixes with dead skin cells that haven't been shed properly, and clogs up the follicle. This can cause whiteheads (when the plug is sealed with skin) and blackheads (when the plug is open to the skin).

Skin bacteria, which are normally harmless, can then infect the plugged follicles. They feast on the sebum and produce a substance that stimulates an immune response, resulting in red and inflamed skin. This leads to types of spots known as papules (pink or red bumps) and pustules (red pimples filled with pus), as well as more severe types of spots.

Pimples appear to be triggered by hormones, namely testosterone, which stimulates sebaceous glands to overproduce sebum. It's for this reason that teenagers going through puberty are more prone to acne, but adults can still get spots too. Pimples can also be hereditary, and can be caused by some cosmetic products and certain medications.

Skin deep

Get a close-up look at a pimple and how it's formed



Skin
Also known as dermis, the skin has tiny pores through which hair grows and sebum and sweat escape.

Clogged pore
This occurs when there is an excess of sebum mixed with dead skin cells, creating a plug in the pore.

Inflammation
Inflammation, where the pimple is red and swollen, is the immune system's response to fighting the infected hair follicle.

Bacterial infection
Skin bacteria, which are normally harmless, can infect the blocked hair follicle and feast on the sebum.

Sebaceous gland
The sebaceous gland normally produces an oily substance called sebum, but in acne, sebum is over-produced.

Hair follicle
Pimples form when hair follicles – the shaft that hair grows out of – become blocked and infected.

Spot be gone!

There's no magic potion to cure spots, but treatments can improve symptoms

While there's no cure to zap zits into oblivion, there are ways to prevent the formation of spots and reduce symptoms. There are many over-the-counter soap and lotion products with active ingredients that help unplug blocked pores, prevent blockages and kill bacteria. In more severe acne cases, a prescription medicine from a doctor may be needed.

Anti-acne products can have side effects, though, and it may take several months before symptoms improve. There are also more radical treatments, such as laser and light therapy, but results from these have been mixed. Of course, there are simple ways to reduce the risk of pimples, such as washing your face (but no more than twice a day), avoiding pimple popping, which can make the infection worse, and keeping greasy hair away from the face.

Shining UV light on hands reveals the bacteria that are lingering on them

How clean are your hands?

Explore the microscopic germ city lurking on your hands

Throughout the day, our hands touch many surfaces – from smartphones and toilet flushes to bus handrails and the pet dog. Bugs on those surfaces transfer to our hands, creating a thriving population of microscopic germs – more than 3,000 different types, in fact. The majority of hand bacteria are good (known as resident flora), but we can also pick up bad bugs, like faecal bacteria (from poo) such as Escherichia coli, alongside other nasties like Staphylococcus aureus and the viruses norovirus (winter vomiting bug) and flu.

These bad bugs spread to surfaces and people's hands when we don't wash our hands after using the toilet or taking out the bins. Then, when we eat or touch our mouths, we ingest them, and that can make us sick. Research shows that the best way to rid hands of unwanted germs and control the spread of infections is to wash hands with soap and water, particularly after using the toilet and before eating. Experts recommend scrubbing hands for the length of time it takes to sing *Happy Birthday* twice. Pass us the soap...

Dirtier than a toilet seat

Smartphones

Interestingly, 11 per cent of people use smartphones and tablets when using the toilet to help pass the time.

Handbags

Over the course of a day, a bag touches lots of grimy surfaces, from restaurant floors to tube seats.

Chopping boards

The average chopping board has over 200 times more faecal bacteria on it than a toilet seat does.

How does dry shampoo really work?

Find out the secret to washing your hair without water

Dry shampoo rids the hair of oil without the need for a shower

Ever had that Monday-morning, bad-hair day when there's no time to jump in the shower? Dry shampoo – the nifty, no-wash alternative – can work wonders. It's essentially a spray-on powder that aims to remove excess oil from your hair. This oil is produced by the sebaceous glands attached to your hair follicles. Normal wet shampooing lifts and washes the oil and grime away, but in the absence of water, the dry shampoo simply soaks up the excess oil.

This action is achieved through the dry shampoo's absorbent ingredients: starch, clay or silica. These fine powders soak up oil like a sponge, creating clumps that can then easily be brushed out of the hair. Most dry shampoos also contain a propellant to blast the powder onto the hair, and some contain alcohol that helps to carry the starch out of the bottle. However, dry shampoo doesn't rid the scalp of hair product, dirt or dead skin cells, so washing hair regularly with water and liquid shampoo is still necessary.

The starch in dry shampoo soaks up the oil in your hair

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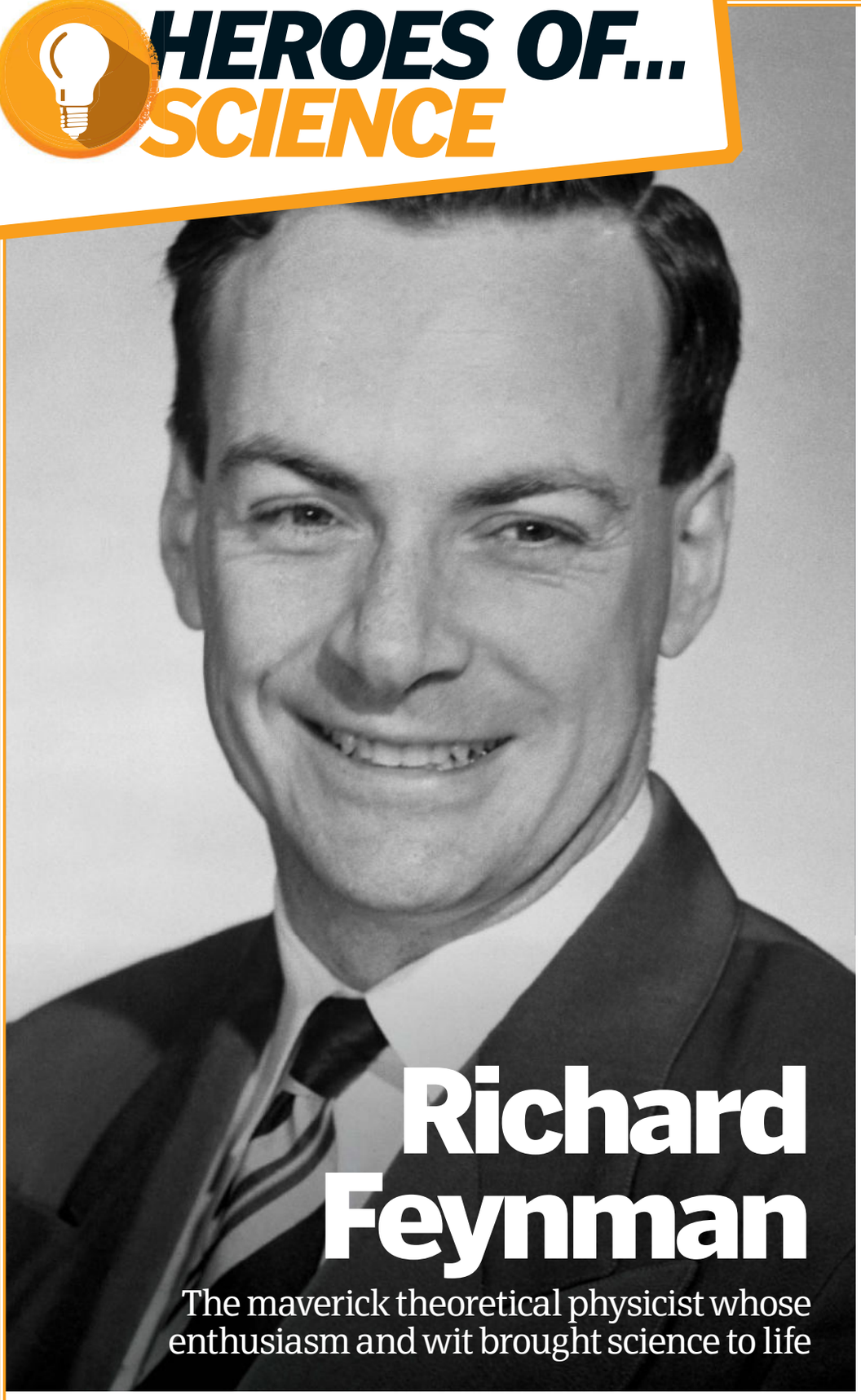


Richard Feynman

The maverick theoretical physicist whose enthusiasm and wit brought science to life

Not many ten-year-olds have their own home laboratory, but Richard Feynman was not like most people. As a child, he had a natural curiosity about how the world works and an exceptional talent for maths and science. By the time he was 15, he had taught himself calculus, advanced algebra and trigonometry. After studying physics at the Massachusetts Institute of Technology (MIT), Feynman went on to achieve record marks in the entrance exams to Princeton University's graduate programme.

Before completing his doctorate, Feynman was recruited by the US government for the top secret Manhattan Project at Los Alamos, New Mexico. Some of the most eminent scientists of the time worked together to create the world's first atomic bombs, which eventually helped the Allies win World War II. Feynman played a key role in predicting the amount of energy released by the bombs, and pioneered the use of computing machines to carry out the huge number of calculations required for the project.

> *"With flamboyant demonstrations and his contagious enthusiasm for the subject, his lectures became legendary"*

During his time at Los Alamos, Feynman would frequently test the boundaries of the project's security measures by picking locks and cracking safes. He became the go-to person for anyone who wanted to retrieve documents from an absent colleague's safe to work on.

After the war, Feynman returned to academia as an associate professor at Cornell University. It was here he completed his work on quantum electrodynamics – using quantum mechanics to explain the interactions between electromagnetic radiation and subatomic particles – that would eventually win him the Nobel Prize (see 'The big idea' boxout). Throughout his career as a professor, first at

A LIFE'S WORK

A closer look at the extraordinary life of one of science's great theoretical thinkers

1918
Richard was born on 11 May 1918 in New York City to Melville and Lucille Feynman.

1928
By the time he's just ten years old, Feynman has his own home laboratory.

1939
He graduates from MIT and achieves perfect scores in the Princeton University graduate school entrance exam.

Feynman admitted he "was interested only in science" while at MIT

1940s
Feynman is recruited for the Manhattan Project at Los Alamos, New Mexico to help build an atomic bomb.

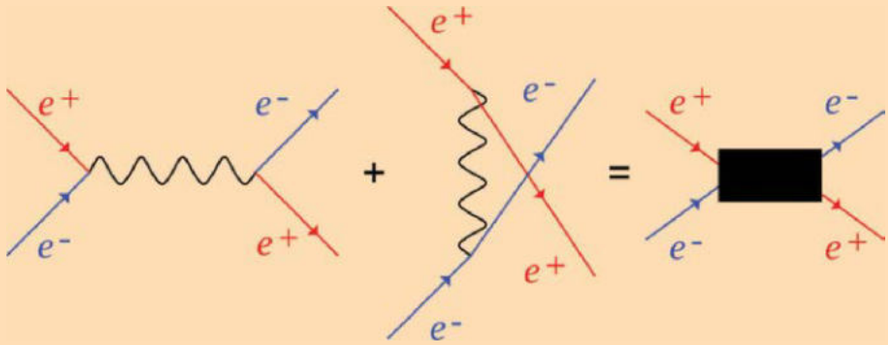
The Manhattan Project's Trinity test was the first atomic bomb detonation

The big idea

Feynman's famous diagrams help physicists visualise particle behaviour

Quantum electrodynamics (QED) is an area of physics that aims to make sense of electromagnetism and subatomic particles. The advent of quantum mechanics highlighted some problems with the classical understanding of how atoms behaved. QED was an effort to resolve this.

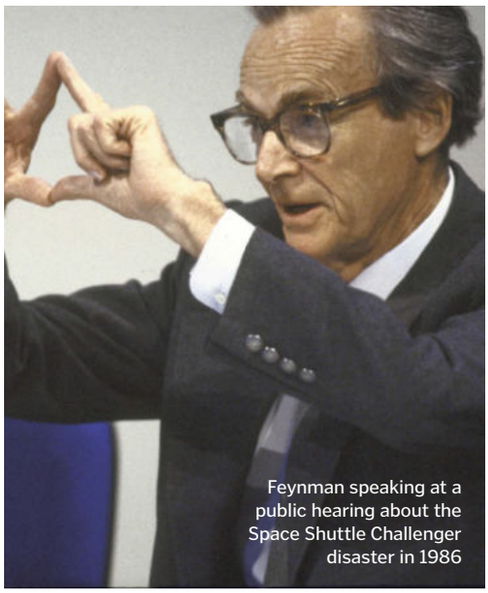
In his typically unconventional style, Feynman approached these issues from a different perspective. Using simple line diagrams, he could bypass a lot of the complicated equations needed for QED. These 'Feynman diagrams' were so effective at visually explaining complex phenomena that they are now used in completely different fields such as galactic evolution. With Feynman's help, QED became the most numerically precise physical theory ever created. As a result of this accomplishment, he shared the 1965 Nobel Prize in physics alongside fellow QED scientists Sin-Itiro Tomonaga and Julian Schwinger.



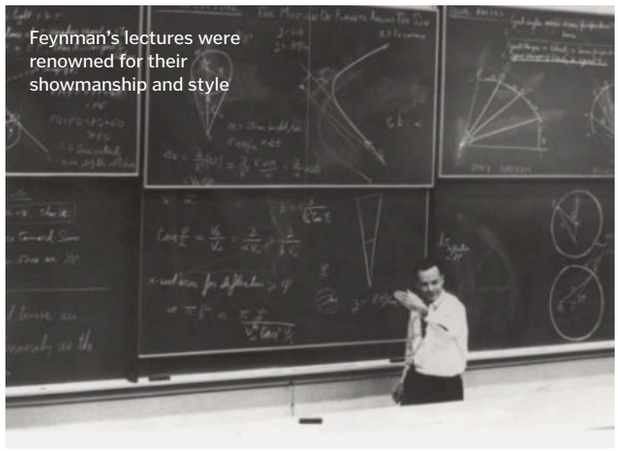
Feynman's simple line drawings help scientists make sense of the complex particle interactions

Cornell and then the California Institute of Technology (Caltech), Feynman became renowned for his creative and unconventional teaching style. With flamboyant demonstrations and his contagious enthusiasm for the subject, his lectures became legendary.

In the late 1970s, Feynman was diagnosed with an abdominal tumour and went through a series of operations to keep the cancer at bay. He survived long enough to join the panel set up to investigate the Space Shuttle Challenger disaster in 1986. The craft had exploded just 73 seconds after launch, tragically killing all seven astronauts on board. After breaking away from the commission's investigation to conduct his own private enquiries, Feynman discovered that a faulty O-ring seal was to blame. The inquiry took its toll however; Feynman was exhausted and his kidneys were failing as a result of his cancer. He decided not to undergo further surgeries and passed away in hospital on 15 February 1988. The world lost a one-of-a-kind scientist, but his boundless enthusiasm for physics lives on through his discoveries, lectures and books, which continue to inspire new generations of physicists.



Feynman speaking at a public hearing about the Space Shuttle Challenger disaster in 1986



Feynman's lectures were renowned for their showmanship and style

Five things to know about... RICHARD FEYNMAN

1 He was a 'rock star physicist'

Feynman had an unusual reputation as a scientist. He would fraternise with his students and hang out in Las Vegas bars.

2 Science ran in the family

As a child, Richard employed his younger sister Joan as his lab assistant for four cents a week. She went on to become an astrophysicist at NASA.

3 He had some quirky hobbies

Feynman had a passion for playing the bongo drums and also taught himself how to decode Mayan hieroglyphs.

4 He married three times

Tragically, Feynman's first wife died of tuberculosis at the age of 25 while he was working on the Manhattan Project.

5 He watched the Trinity explosion

Feynman was the only person to observe the test without dark safety glasses. He watched through a truck windshield to protect against the intense UV light.

1965
He shares the Nobel Prize in physics for his work on quantum electrodynamics and 'Feynman diagrams'.

1960s
Feynman rewrites the Caltech undergraduate syllabus. To this day, the Feynman Lectures remain popular books.

Feynman's creative explanations are still widely read by physics students

1986
After the Space Shuttle Challenger explodes, Feynman is asked to help investigate the cause of the disaster.

The Challenger investigation revealed a faulty O-ring was responsible for the explosion

1988
Following a battle with abdominal cancer, Feynman dies on 15 February 1988, aged 69.

60 SECOND SCIENCE

Electricity explained

THE SHOCKING SCIENCE OF CIRCUITS, CURRENTS AND VOLTS

BACKGROUND

Electricity is a form of energy, and in combination with magnetism, it makes up one of the four fundamental forces of the physical world. It is generated by the movement of electrons, which are subatomic particles that orbit the nuclei of every atom.

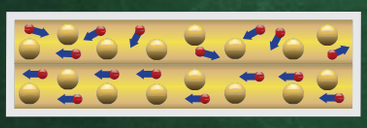
In many materials, such as wood and plastic, electrons are held tightly alongside their atoms, but in some materials, such as metal, they can break free and move around on their own. Electrons have a negative charge, and it is the movement of this charge that creates electricity.

IN BRIEF

For electrons to move around and create a current, there has to be a circuit. This is a closed loop that allows a steady flow of electrons, carrying tiny amounts of electrical energy as they go.

Circuits can be made from solid materials like copper wire, which have free electrons to carry the charge, and they can also be made from fluids containing charged ions, such as the salty fluid in our bodies, or from gases, such as air during a lightning strike.

A circuit on its own isn't enough to produce an electric current; a voltage, or potential difference, is needed to get things moving. This can be provided by a battery, a generator, or by the build-up of static.

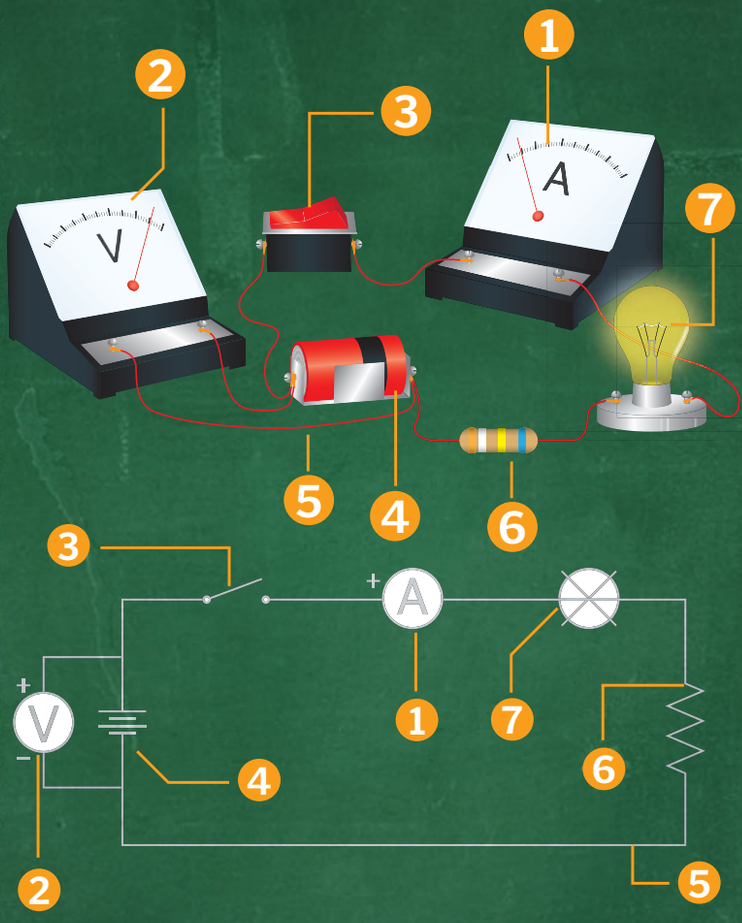


SUMMARY

Electricity is produced by the movement of charged particles - electrons or ions. It requires a complete circuit to flow, and it needs a potential difference to get the electrons moving.

Circuits uncovered

Discover the key components in a simple electrical circuit



1 Ammeter (in series)
Current is measured in amps. An ammeter can tell you the size of the current flowing through part of a circuit.

2 Voltmeter (in parallel)
Potential difference is needed to make a current flow, and it is measured in volts. Voltmeters can tell you the size of the potential difference across part of a circuit.

3 Switch
Circuits must be joined into a closed loop before current can flow. An open switch breaks the circuit.

4 Cell (or battery)
Batteries produce the potential difference that drives electrons around the circuit.

5 Wires
Wires connect up the components, providing a path for electrons moving around the circuit.

6 Resistor
This component reduces the flow of electricity, and is used to lower the voltage in a circuit.

7 Lamp
A filament lamp heats up and starts to glow as current passes through.

THE STORY OF ELECTRICITY

SOME OF THE FIRST EXPERIMENTS WITH ELECTRICITY WERE PERFORMED BY THE ANCIENT GREEKS, WHO OBSERVED THAT IF YOU RUBBED AMBER AGAINST FUR, IT WOULD ATTRACT DUST AND OTHER SMALL PARTICLES. IN FACT, THE WORD ELECTRICITY COMES FROM THE GREEK WORD FOR AMBER – ELEKTRON.

IT WASN'T UNTIL THE EXPERIMENTS WERE REPEATED IN THE 17TH AND 18TH CENTURY THAT THE SCIENCE OF ELECTRICITY STARTED TO EMERGE. AT FIRST, IT WAS THOUGHT THAT ELECTRICITY WAS A FLUID, AND DUTCH SCIENTISTS BUILT 'LEYDEN JARS' TO CONTAIN IT. THE GLASS JARS HAD METAL INSIDE AND OUT, AND COULD STORE A STATIC CHARGE.

IN 1752, BENJAMIN FRANKLIN DESCRIBED AN EXPERIMENT TO DEMONSTRATE THAT LIGHTNING WAS ELECTRICITY: BY FLYING A KITE WITH A KEY ATTACHED TO ITS STRING DURING A THUNDERSTORM. IN THE 1800S, ALESSANDRO VOLTA DISCOVERED THAT ELECTRICAL POTENTIAL COULD CAUSE AN ELECTRICAL CHARGE TO FLOW. HE USED THIS KNOWLEDGE TO INVENT BATTERIES.

SECRETS OF THE SPECIAL FORCES

DISCOVER THE CUTTING-EDGE TECH & KILLER TRAINING OF THE WORLD'S ELITE SOLDIERS

Born in the dark days of World War II, they were known as 'special services'. Squaddies and GIs knew better than to ask questions when one of their mates disappeared into one of these 'private armies'. Small units of unconventional soldiers like the British Army's Commandos or the US Army's Rangers sprung up to accomplish specific, and highly dangerous, missions.

One of the first was the famous raid on the French port of Dieppe in August 1942 and was conducted by a joint force of Commandos and Rangers. Designed to demonstrate that the Allies could launch raids against German occupied France, the operation was a failure, with half of the force killed or captured.

Two other British units, the Long-Range Desert Group and the Special Air Service (SAS) were, however, finding more success in North Africa. These bearded soldiers wore Bedouin garb and travelled in Jeeps festooned with machine guns, striking German airstrips and supply dumps.

These early missions parallel the core roles of today's Special Forces: working alongside local resistance fighters or mentoring government counter-insurgency forces; long range reconnaissance and surveillance; and direct action missions targeting high value targets.

The SAS and its maritime equivalent the Special Boat Squadron (SBS), along with the Rangers, survived the war in one form or another while many were disbanded. However, the Cold War saw a resurgence in the idea of covert units. The Green Berets and the Navy SEALs (SEa-Air-Land) were established in the 1950s and thrown into the cauldron of the Vietnam War.

Today's Special Forces 'operators' have become synonymous with the war on terror. From the hunt for terrorist leaders in Syria to counter-terrorism on the streets of Paris and Brussels, Special Forces stand ready to rescue hostages or respond to the latest terrorist incidents.

Only the toughest need apply

A rare mixture of physical and mental endurance is needed to pass 'selection'

Candidates for service in a special operations unit are typically older than the average soldier and will have completed at least one term of service with a clean record. They will be among the best soldiers of their parent units.

Once accepted for selection, the soldier will need to be superbly physically fit to simply survive the course. Many train for more than a year prior to attending selection, focusing on cross-country marches carrying heavy packs.

But potential Special Forces soldiers or Navy SEALs need one trait over any other – the willpower to keep going no matter what is thrown at them. Fitness will keep them moving but only mental toughness will overcome the sleep deprivation and the pain in their bodies.

Soldiers who are strong, consistent performers are most likely to pass. Veterans of UK Special Forces selection for many years advise candidates to be the 'grey man' – blending in to the group and listening rather than talking. This applies more so once an individual joins the unit.

The selection course for most units can last anything up to a year before a candidate is finally considered a member of the unit. They can be 'binned' at any time during this process. Only those suffering a genuine injury may be permitted to try again. Even the strongest candidates can fail, however. Tragically, some even lose their lives – in 2013, three candidates for SAS selection died and a Navy SEAL drowned in 2016 during the infamous Hell Week.

Once they are a member of a special operations unit, the soldier or sailor needs to maintain their fitness and skills or face the dreaded RTU (Returned to Unit). In the US Army's Delta Force, operators are expected to be responsible for their own training regime and are under constant scrutiny from unit psychologists and other training staff.

ABOVE Potential US Navy SEALs crawl through the surf at the mercy of their instructor

LEFT An exhausted trainee carrying a simulated casualty during a US Army Special Forces Qualification Course

BELOW Green Berets learn to operate and survive in harsh, sub-zero conditions

© Shutterstock; WIKI

DID YOU KNOW?

The SAS selection process lasts five months and has a 90 per cent fail rate

Meet the expert

Leigh Neville is an Australian military historian and author of *Guns of the Special Forces*, *Special Forces in the War on Terror* and *Modern Snipers*, all available now. For more information, visit his website at www.leighneville.com

Training the world's elite

The gruelling reality of becoming part of the toughest fighting force

'Surfing' is designed to test the endurance and perseverance of candidate SEALs

A SERE student starting a fire during a winter course

SEAL candidates perform the infamous 'Log PT' during Hell Week

HELL WEEK

Prospective Navy SEALs must survive an extreme test of endurance known as Hell Week. The course is comprised of five days of constant physical exertion on just a few hours sleep. Candidates are subjected to long distance marches and swims, obstacle courses and log runs, all while wet, exhausted and covered in mud!

SURVIVAL, EVASION, RESISTANCE AND ESCAPE

Survival, evasion, resistance and escape (SERE) training teaches techniques of how to find shelter and sustenance, how to escape a pursuing enemy (including evading tracking dogs), and how to survive eventual capture and torture by the enemy. Many consider this final phase, known as RTI or Resistance-To-Interrogation within UK Special Forces, to be the toughest.

A bird's eye view of operators negotiating a US Army 'Kill House'

THE KILLING HOUSE

All new operators train in close quarter battle, or CQB. The SAS does much of this training in a specially constructed building called the 'Killing House', which offers 360-degree shooting and projected video scenarios. CQB teaches instinctive and pinpoint shooting, often within inches of live hostages; door breaching using shotguns and explosives; and clearing rooms using stun grenades known as flashbangs.

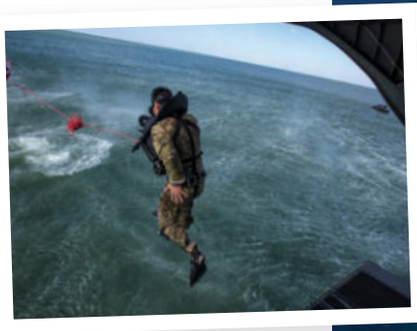
DID YOU KNOW?

Hell Week is said to be the toughest training in the US military. On average, only 25 per cent of Navy SEAL candidates are successful

COMBAT DIVING

Closely associated with the Navy SEALs and SBS, combat diving or 'frogman' training instructs operators in the use of closed-circuit SCUBA rebreathers (that eliminate tell-tale bubbles) and mini submarines called Swimmer Delivery Vehicles (SDVs). The two-man Torpedo SDV can even be launched from the torpedo tube of a nuclear submarine.

A Navy SEAL climbs aboard an SDV docked to a submarine



A Special Forces soldier wearing fins practises leaping from a helicopter directly into the water

US Army Rangers conduct first aid training in Afghanistan while wearing night vision goggles

"Other techniques like loop-holing are used to blow holes through walls"

Polish and US operators fast-rope from a hovering MH-60L during a joint exercise

A 3rd Special Forces Group operator conducts a HALO jump in Korea

HIGH ALTITUDE LOW OPENING (HALO)

Along with static line parachuting, operators are taught both high (HAHO) and low (HALO) opening techniques. Both require oxygen masks and see operators jumping from the cruising altitude of an airliner. HALO is used to allow aircraft to fly above enemy radars, while operators can glide for many miles using HAHO.

URBAN WARFARE

Known as MOUT (Military Operations in Urban Terrain) or FIBUA (Fighting In Built-Up Areas), operators are taught to insert onto rooftops from helicopters before using demolitions to open a door or assault ladders to access neighbouring structures. Other techniques like loop-holing are used to blow holes through walls to gain access to terrorist strongholds.

The British SAS versus the US Navy SEALs

Who's the best at what they do and why?

Although both accomplish some of the same missions, the SEALs and SAS are very different organisations. Firstly, the SAS numbers around 300 'badged' operators while the US Navy has over 8,000 SEALs divided into ten officially recognised Teams.

SEALs conduct a wide range of primarily maritime missions including beach reconnaissance, hydrographic surveys, and short duration raids and ambushes on coastal targets. Many are stationed at sea, where they support the Marines.

Since the 9/11 attacks, the SEALs have increasingly worked a long way from the water in places like land-locked Afghanistan, where they have carried out the full spectrum of special operations. This includes training local forces and long reconnaissance missions like that portrayed in the film and book *Lone Survivor*.

A more apt comparison is perhaps between the SAS and SEAL Team 6, often referred to by their cover name as the Naval Special Warfare Development Group. Team 6 are the elite of the SEALs, trained in many of the same skills as the SAS, who they often operate alongside.

In fact, SEALs from Team 6 worked in conjunction with the British SAS to rescue a number of hostages in eastern Afghanistan back in 2012, on a mission called Operation Jubilee. The hostages were held in two cave complexes

Essential kit

What specialist equipment do the SAS and Navy SEALs carry on their dangerous missions?

US Navy SEAL

Helmet
The Ops-Core FAST helmet is designed like a skateboard helmet with ballistic properties to protect against bullets and shrapnel.

AOR camouflage
SEALs wear their own digital camouflage, known as AOR or Area of Responsibility. AOR1 worn here is for the desert, whereas AOR2 is for woodland or jungle.

MP7A1 submachine gun
The 4.6mm Heckler and Koch MP7A1 is favoured due to its remarkable quietness when fitted with a suppressor (silencer).

Plate Carrier
The Crye Plate Carrier holds both armour plates that will stop AK47 rounds and pouches for ammunition, grenades and radios.

Spare magazines
SEALs carry surprisingly little ammunition when conducting raids or assaults. Many carry only three extra magazines to reduce weight.

Aimpoint sight
The Aimpoint Micro T-1 is a red dot sight used on SEAL MP7s and HK416 rifles to increase accuracy.

"Since 9/11, the SEALs have increasingly worked a long way from water"

SPECIAL FORCES AROUND THE WORLD

America's Delta Force
The US Army's Tier One special missions unit was responsible for capturing Saddam Hussein and killing Musab al Zarqawi, al-Qaeda leader in Iraq.

Germany's GSG9
GSG9 was the first dedicated counter-terrorist unit. It famously stormed a hijacked Lufthansa airliner in 1977, rescuing all 86 hostages.

Australia's SASR
Known as the 'Phantoms of the Jungle' in Vietnam, Australia's Special Air Service Regiment has been deployed to Somalia, East Timor, Iraq and Afghanistan.

France's GIGN
The Groupe d'Intervention de la Gendarmerie Nationale is France's national counter-terrorist unit made famous for neutralising the *Charlie Hebdo* killers.

British SAS

Helmet
The SAS uses the Crye Airframe helmet with MultiCam cover. It is fitted with rails that allow lights and cameras to be mounted.

L119A2 assault rifle
This Canadian assault rifle used by the SAS features rails for mounting weapon lights, foregrips and sights.

Glock 19 pistol
The compact 9mm Glock 19 has replaced older Sig Sauer P226 pistols in a move mirrored by the SEALs.

Hiking boots
Like the SEALs, the SAS favour commercial hiking boots that are lighter and sturdier than issue combat boots.

ACOG sight
UK Special Forces favour the Trijicon ACOG or Advanced Combat Optical Gunsight, which offers four-power magnification of targets.

MultiCam camouflage
The SAS and SBS were the first to wear Crye MultiCam before the wider British Army adopted a modified version of it.

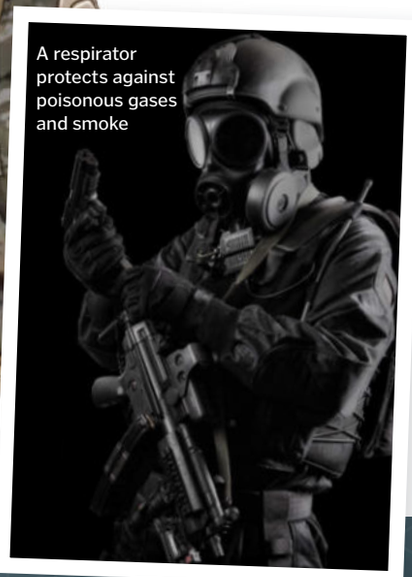
DID YOU KNOW?
Counter-terrorism only began to be added to the SAS's responsibilities in the 1970s

that were assaulted by a joint force of SAS and SEAL operators, freeing the hostages unharmed and killing all 13 insurgents.

SEAL Team 6 and the SAS both train extensively in direct action missions targeting enemy leadership - such as the raid on Osama bin Laden's compound in Pakistan in 2011 - covert reconnaissance and counter-terrorism. Both units rotate duty in their respective countries as the national counter-terrorist stand-by force, ready to rescue hostages or intervene should terrorists get their hands on a Weapon of Mass Destruction.

While 'regular' SEALs could carry out a hostage rescue, they receive only limited training in the advanced close quarter battle skills required. Team 6 and the SAS are both also extensively trained to conduct deniable undercover operations where their very presence is unacknowledged.


Plain-clothes British SBS operators in Afghanistan in November 2001


A respirator protects against poisonous gases and smoke

The Navy version of the SAS?

The Special Boat Service or SBS are organised and trained in a similar fashion to the better-known Army unit but have a primarily maritime role. Like the SEALs however, the need for Special Forces has seen the SBS increasingly deploy on missions that would have traditionally fallen to the SAS.

In fact, they are trained in many of the SEAL missions but also specialise in counter-terrorism, including recovering cruise ships or oil platforms seized by terrorists. The SAS still dominate on land-based missions but the SBS were responsible for special operations in Afghanistan for many years while the SAS focused on Iraq.

A long-standing animosity exists between the SAS and SBS that dates back to World War II. It has only increased as the SBS has been given a greater 'slice of the pie' since 9/11, including a slot as the national counter-terrorist response, a role pioneered by the SAS.

Italy's NOCS
The Italian Nucleo Operativo Centrale di Sicurezza is best known for rescuing a kidnapped American General from Red Brigades terrorists.

UK's SRR
The Special Reconnaissance Regiment is one of the newest UK Special Forces units. It was formed in 2005 to conduct reconnaissance in 'denied' areas.

Canada's JTF-2
Joint Task Force 2 are the Canadian Tier One special operation unit, currently deployed to Iraq as part of the counter-Islamic State mission.

Russia's Alfa Group
Alfa or Spetsgruppa-A is part of the FSB intelligence agency. Alfa was prominent at the notorious Moscow Theatre Siege in 2002.

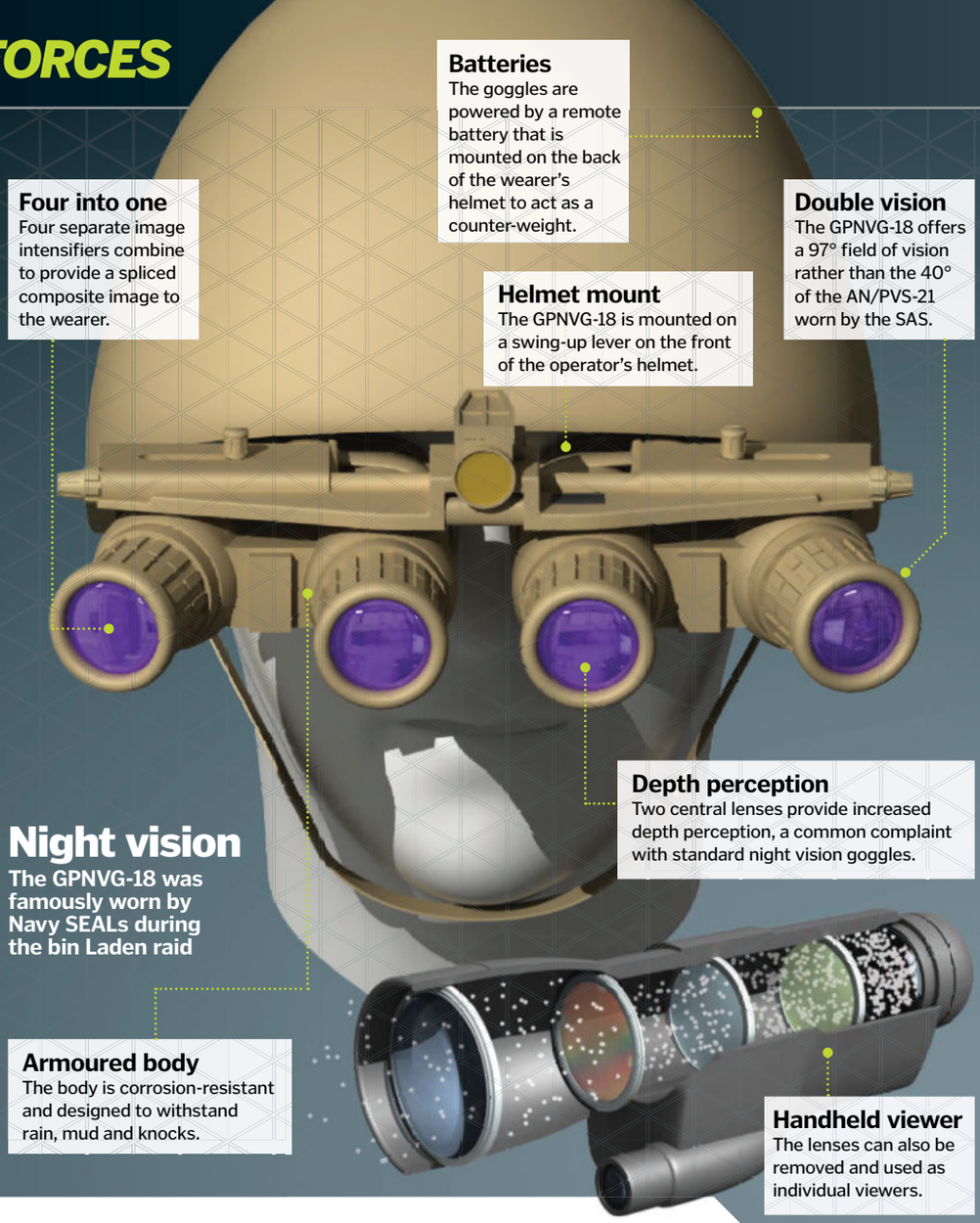
Weapons and tech

Special Forces use the latest innovations to hunt down terrorists and insurgents

Since their inception in the 1940s, Special Forces units have adapted the best kit to suit their unique missions. Today, they can bypass normal government procurement processes, allowing them to purchase what they need off-the-shelf or finance research and development.

The biggest improvements in Special Forces technology have centred upon three areas: surveillance, ballistic protection and so-called diversionary devices. Units use a range of unmanned ground and aerial vehicles to conduct reconnaissance upon targets including the latest nanotechnology, providing real-time streaming imagery even in low-light conditions.

Once they have located their enemy, operators storming a terrorist safe house benefit from increasingly lighter and stronger body armour, and helmets that can stop the bullet from an AK-47. To give them the vital seconds needed to breach a target location, they use the latest generation of the flashbang grenade like the Rheinmetall MK13 to disorient and temporarily stun the enemy.



Batteries
The goggles are powered by a remote battery that is mounted on the back of the wearer's helmet to act as a counter-weight.

Four into one
Four separate image intensifiers combine to provide a spliced composite image to the wearer.

Double vision
The GPNVG-18 offers a 97° field of vision rather than the 40° of the AN/PVS-21 worn by the SAS.

Helmet mount
The GPNVG-18 is mounted on a swing-up lever on the front of the operator's helmet.

Depth perception
Two central lenses provide increased depth perception, a common complaint with standard night vision goggles.

Night vision
The GPNVG-18 was famously worn by Navy SEALs during the bin Laden raid

Armoured body
The body is corrosion-resistant and designed to withstand rain, mud and knocks.

Handheld viewer
The lenses can also be removed and used as individual viewers.

Micro Unmanned Aerial Vehicle (UAV)

The Black Hornet UAV is just one example of the latest developments in miniaturising unmanned aerial vehicles. This tiny helicopter, only ten centimetres long, carries a full-motion video camera that can be beamed back to a handheld viewer carried by the Special Forces operators.

Currently in service with Australian, British, Norwegian and US Marine special operations units, the latest version offers low-light and night vision capabilities and has been successfully deployed on operations in Afghanistan.

A micro-UAV can enter rooms to locate hostages or bombs

A flashbang detonating before operators storm a room

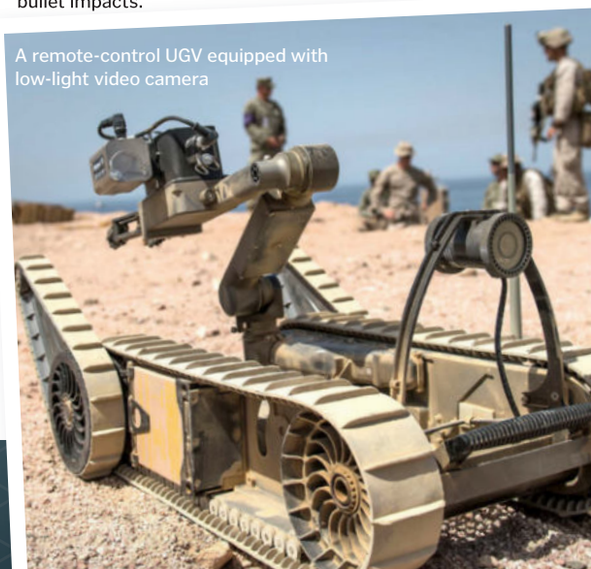
The flashbang

Designed by the SAS in the 1970s and first deployed by GSG9 in 1977, the flashbang takes its name from the two functions of this non-lethal grenade. The 'flash' that temporarily blinds the enemy for up to four to five seconds is provided by the detonation of magnesium powder. The 'bang' of that detonation is typically amplified to 175 decibels – louder than a shotgun being fired.

The latest versions of flashbangs provide multiple detonations. Others add riot gas to the mix or pulse like a strobe. Non-lethal, older models were pyrotechnic, famously causing the fire at the 1980 Iranian Embassy seige in London, for instance.

Unmanned Ground Vehicle (UGV)

UGVs began life as bomb disposal robots but their capabilities for surveillance and reconnaissance were quickly recognised. Today's UGVs offer streaming video, including thermal and night vision, and directional microphones to listen in on terrorist conversations. The latest version can negotiate stairs and even survive grenade blasts and bullet impacts.



A remote-control UGV equipped with low-light video camera

Special operators on special missions

Outnumbered, outgunned and far from home, these are the missions of the Special Forces

SEAL Team 6 operators disembarking from a CH-47 helicopter

Operation Octave Fusion January 2012

SEAL Team 6 conducted their most ambitious rescue in January 2012 after an American NGO worker named Jessica Buchanan and a Danish colleague conducting land mine awareness training in Somalia were kidnapped by pirates. After the pirates' refusal of a $1.5 million (£1.1 million) ransom payment, and with Buchanan's health failing, the decision was made to attempt a rescue. SEAL Team 6 conducted a night-time parachute jump into the Somali countryside, landing at an off-set drop zone. Wearing night vision goggles, they marched the two kilometres to the pirate camp in order to maintain the element of surprise. The SEALs then launched a pre-dawn assault, using flashbang grenades to stun the pirates and kill all nine of the hostage takers. Both hostages were safely recovered.

Operation Nimrod April 1980

On 30 April 1980, six Iraqi terrorists seized control of the Iranian Embassy in London, sparking off one of the most famous Special Forces operations in history. They took 26 hostages, including a policeman and several BBC staff.

After a hostage was murdered, control of the incident was temporarily handed to the British Army's SAS. The unit had been standing by since the start of the siege in case their specialist training and equipment was needed.

An SAS Sabre Squadron conducted a textbook assault on the Embassy, abseiling into position from the roof and using explosive 'frame charges' to blow in the armoured windows of the Embassy. Other teams breached the building from the ground floor.

In an assault lasting just 17 minutes, all of the terrorists bar one were shot dead by the SAS and all surviving 19 hostages were rescued unharmed.

SAS operators prepare to detonate a frame charge during Operation Nimrod

DID YOU KNOW?

Despite what is portrayed in television thrillers, laser sights visible to the human eye are rarely used

US Army Green Berets from Task Force Viking working alongside Kurdish Peshmerga in 2003

Operation Viking Hammer March 2003

During the invasion of Iraq, some 700 Ansar al-Islam terrorists were located in the north of the country. One of their leaders was Musab al-Zarqawi, future head of al-Qaeda in Iraq. The mission to destroy the terrorist safe haven went to the Green Berets of the 3rd and 10th Special Forces Groups. The camp was first struck from the air by a bombardment of cruise missiles. This was followed by a ground assault of Kurdish Peshmerga fighters supported by the Green Berets. Several days of ferocious battles ensued against the dug-in terrorists. During the battle, 22 Peshmerga were killed but remarkably no Green Berets lost their lives. The surviving terrorists eventually fled toward Iran. AC-130 gunships provided air support with nightly missions. Some 300 Ansar al-Islam fighters were killed and their camp captured, including stocks of poisons and biohazard suits.

ABOVE US Army Rangers, wearing night vision goggles, with their Combat Assault Dog in Afghanistan, 2012

LEFT Australian Commandos in a fierce firefight with Taliban insurgents in Afghanistan, 2011

The final option

How Special Forces tackle a terrorist siege

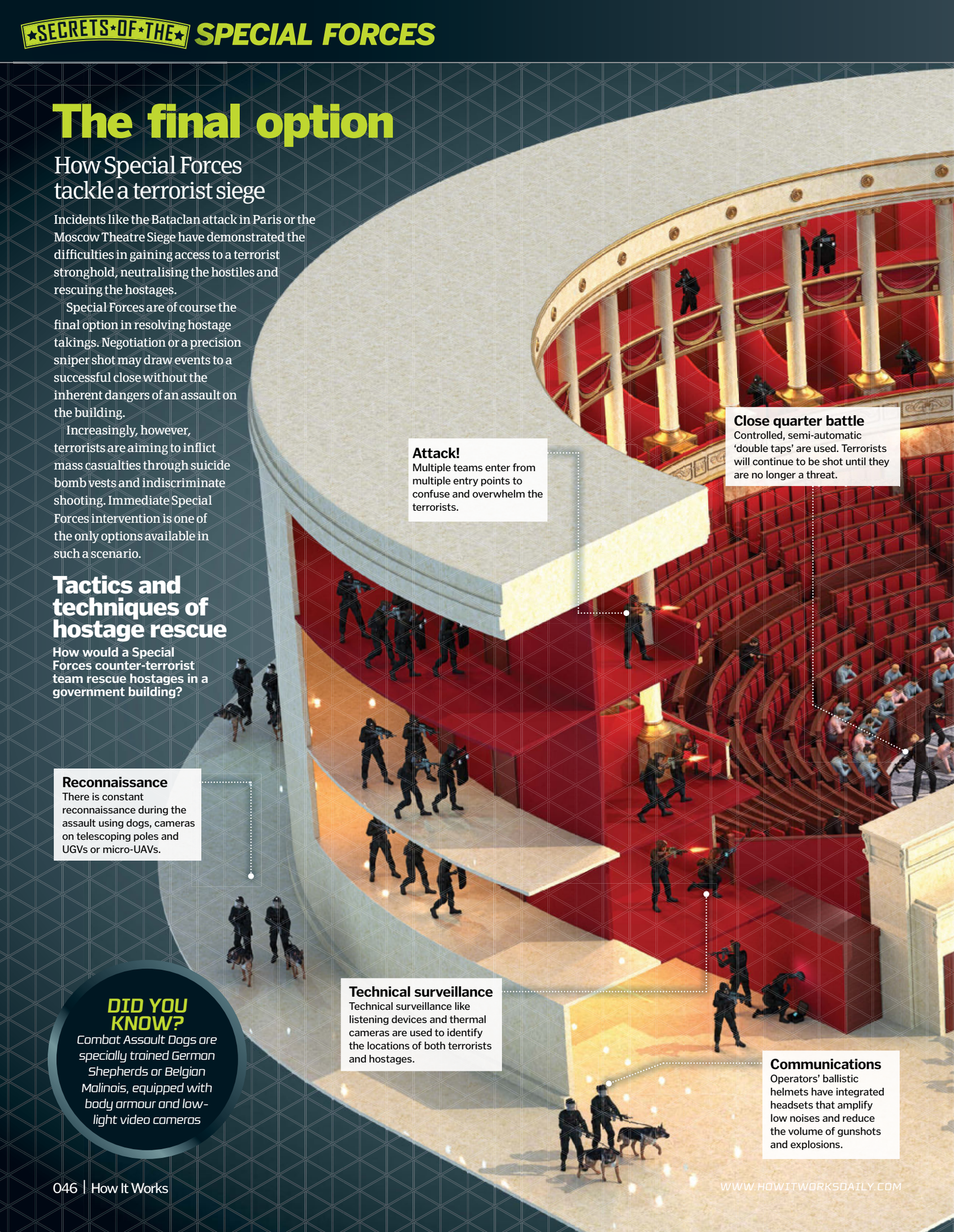
Incidents like the Bataclan attack in Paris or the Moscow Theatre Siege have demonstrated the difficulties in gaining access to a terrorist stronghold, neutralising the hostiles and rescuing the hostages.

Special Forces are of course the final option in resolving hostage takings. Negotiation or a precision sniper shot may draw events to a successful close without the inherent dangers of an assault on the building.

Increasingly, however, terrorists are aiming to inflict mass casualties through suicide bomb vests and indiscriminate shooting. Immediate Special Forces intervention is one of the only options available in such a scenario.

Tactics and techniques of hostage rescue

How would a Special Forces counter-terrorist team rescue hostages in a government building?



Attack!
Multiple teams enter from multiple entry points to confuse and overwhelm the terrorists.

Close quarter battle
Controlled, semi-automatic 'double taps' are used. Terrorists will continue to be shot until they are no longer a threat.

Reconnaissance
There is constant reconnaissance during the assault using dogs, cameras on telescoping poles and UGVs or micro-UAVs.

Technical surveillance
Technical surveillance like listening devices and thermal cameras are used to identify the locations of both terrorists and hostages.

Communications
Operators' ballistic helmets have integrated headsets that amplify low noises and reduce the volume of gunshots and explosions.

DID YOU KNOW?

Combat Assault Dogs are specially trained German Shepherds or Belgian Malinois, equipped with body armour and low-light video cameras

Snipers
The assault is covered by snipers who are trained to fire over the heads of the assault teams, or deliver tear gas.

"One shield used at the Bataclan was hit by more than 20 rounds from an AK47"

Hostage recovery
Hostages are moved to a hostage reception area for identification and medical treatment while the building is searched for explosives.

Distraction devices
All manner of distraction devices are used to gain vital seconds: CS gas, flashbang grenades, and even strobing, high intensity lights.

Immediate Action (IA) plan
This is only triggered by hostile terrorist actions, such as the execution of a hostage, forcing an immediate assault to save lives.

Method of entry
There are four types of breaching: mechanical (like pneumatic jaws), ballistic (including shotguns), thermal (cutting tools) and explosive.

Ballistic assault shields
These provide protection against gunfire. One shield used at the Bataclan siege was hit by more than 20 rounds from an AK47.

Deliberate Action (DA) plan
This allows operators to conduct an assault at the time and place of their choosing, reducing risk and casualties.

LEFT A counter-terrorist team clad in black Nomex flight suits and respirators carrying MP5 sub-machine guns

ABOVE Counter-terrorist operators travel aboard Blackhawk helicopters, ready to fast-rope onto their target

NEXT-GEN RACE CARS

Revealed: Tech innovations that will change the future of racing

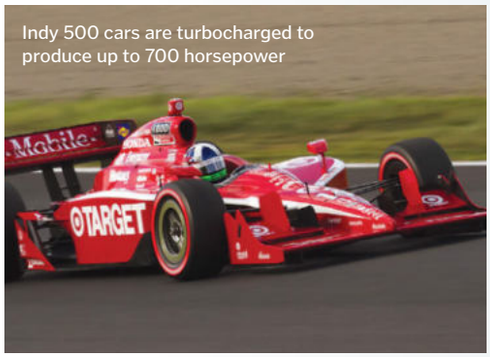
When you think of motorsport, what do you see? Heroic drivers piloting purpose-built high performance machines, or merely loud and dirty cars needlessly polluting the planet? While enthusiasts for the likes of Formula 1, the Indy 500 or Le Mans 24-hour races may opt for the former, it's fair to say there's a perception of the latter among the wider realms of society. However, what you may not know is that, aside from the obvious objective of winning, car manufacturers have always used motorsport as a proving ground for automotive evolution. Engines, suspensions and even the body design of the cars you see on the road today were all originally pioneered on the racetrack, an uncompromising environment where designs and creations are tested to the limit. Without racing we wouldn't have wings or spoilers, turbochargers, or even double-clutch gearboxes. And this evolution isn't always in the name of speed. All of the above has been used to make cars not only faster but cleaner too, increasing efficiency of the engine and therefore reducing fuel consumption, meaning cars can cover a far greater distance before needing to refuel.

And, in our digital age, this gradual evolution has become a sprint to evolve the capabilities of the automobile, beginning of course on the racetrack. In recent years we've witnessed a marked increase in hybrid cars on our roads, which is no coincidence when you consider that the likes of Toyota and Porsche, two of the hybrid market's biggest players, have been racing with hybrids in top-level endurance racing for the last five years.

We can therefore look to current technologies in motorsport to understand what lies ahead in the immediate future of road travel, and that centres around hybrid technology and cars harvesting – rather than merely expending – energy. Vehicles with both internal combustion engines and electric cells are therefore going to be ever more common on the road, with electric energy garnered from recycling old energy when a car is braking.

> "Cars you see on the road today were originally pioneered on the racetrack"

As for the future of racing itself? Well, there's no question it lies with electric power. The World Endurance Championship, responsible for races such as the legendary 24 Hours of Le Mans, are stipulating rules for ever-cleaner cars, while championships such as Formula E are already bringing electric cars to the world stage. If you understand what's happening in racing today, you can see what you're going to be driving on the road in the coming years.



Indy 500 cars are turbocharged to produce up to 700 horsepower


The 24 Hours of Le Mans race has been held almost every year since 1923

F1 has led the way for many years as the most popular form of motor racing

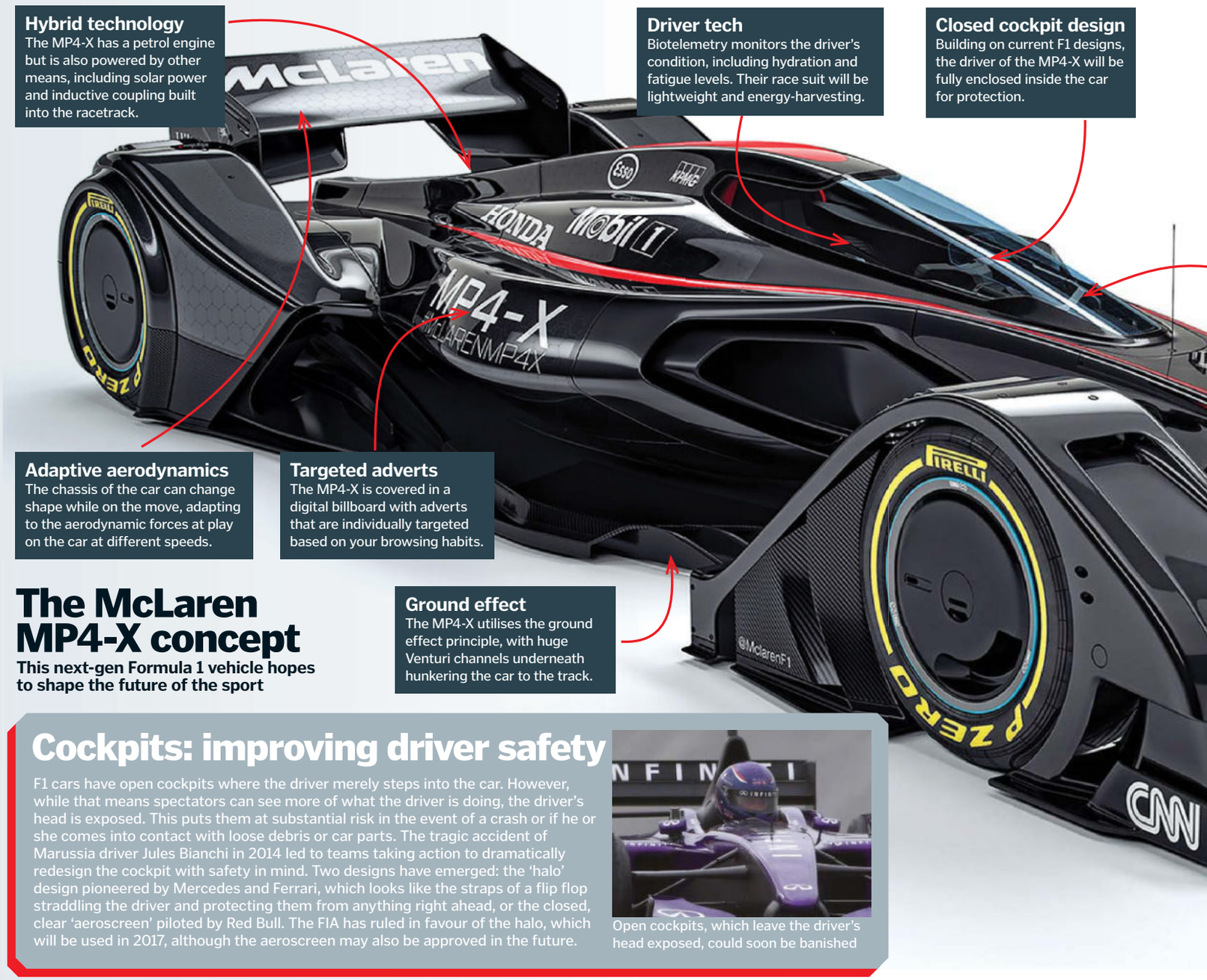
Formula 1 vs Formula E

Which is the future of top-level motor racing?

They may sound like similar motorsport disciplines but Formula 1 (or F1) and Formula E (FE) are different entities altogether. F1 is the long-established championship, offering a global sport that takes the concept of single-seat racing to its most extreme. It has the fastest cars, the history dating back to 1950, and the legends that many generations of motorsporting fans look up to. FE, on the other hand, is something of a new, breakaway phenomenon. Started in 2014, FE uses fully-electric cars with an eye on sustaining energy rather than merely consuming it. Confronting its biggest challenge, FE has sought to make e-racing an attractive proposition for spectators, and so the cars look very similar to their F1 counterparts.

In recent years F1 has started to adopt more green-oriented tech too, with energy recuperation systems effectively dubbing the cars as hybrids. In 2014 the FIA (the governing body for F1) ordered that all cars must cut the amount of fuel they use in a race by a third.

FE is unlikely to be a threat to the commercial success of F1. This is because while F1 visits the world's best circuits, FE makes do with street circuits that don't make for great television, with ugly barriers mapping out courses on bumpy, drain-lined roads rather than sweeping circuits with purpose-built race kerbs. Also, part of the allure of motor racing is the banshee sound of the hard-working engines in race cars, rather than the Scalextric-like whine of electric cars, which gives F1 the upper hand. So it's unlikely that FE will take centre stage anytime soon, and we'll more likely see an adoption of pure electric technologies by F1 teams in the coming years.



Hybrid technology
The MP4-X has a petrol engine but is also powered by other means, including solar power and inductive coupling built into the racetrack.

Driver tech
Biotelemetry monitors the driver's condition, including hydration and fatigue levels. Their race suit will be lightweight and energy-harvesting.

Closed cockpit design
Building on current F1 designs, the driver of the MP4-X will be fully enclosed inside the car for protection.

Adaptive aerodynamics
The chassis of the car can change shape while on the move, adapting to the aerodynamic forces at play on the car at different speeds.

Targeted adverts
The MP4-X is covered in a digital billboard with adverts that are individually targeted based on your browsing habits.

Ground effect
The MP4-X utilises the ground effect principle, with huge Venturi channels underneath hunkering the car to the track.

The McLaren MP4-X concept

This next-gen Formula 1 vehicle hopes to shape the future of the sport

Cockpits: improving driver safety

F1 cars have open cockpits where the driver merely steps into the car. However, while that means spectators can see more of what the driver is doing, the driver's head is exposed. This puts them at substantial risk in the event of a crash or if he or she comes into contact with loose debris or car parts. The tragic accident of Marussia driver Jules Bianchi in 2014 led to teams taking action to dramatically redesign the cockpit with safety in mind. Two designs have emerged: the 'halo' design pioneered by Mercedes and Ferrari, which looks like the straps of a flip flop straddling the driver and protecting them from anything right ahead, or the closed, clear 'aeroscreen' piloted by Red Bull. The FIA has ruled in favour of the halo, which will be used in 2017, although the aeroscreen may also be approved in the future.

Open cockpits, which leave the driver's head exposed, could soon be banished

Formula E's future car

Mahindra Racing's concept is a peek into the future of the sport

Carbon-fibre body
Mahindra's concept has a body made entirely of carbon fibre, meaning it is strong and light.

Aero-scoops
This concept experiments with a scoop-shaped rear instead of the traditional wing.

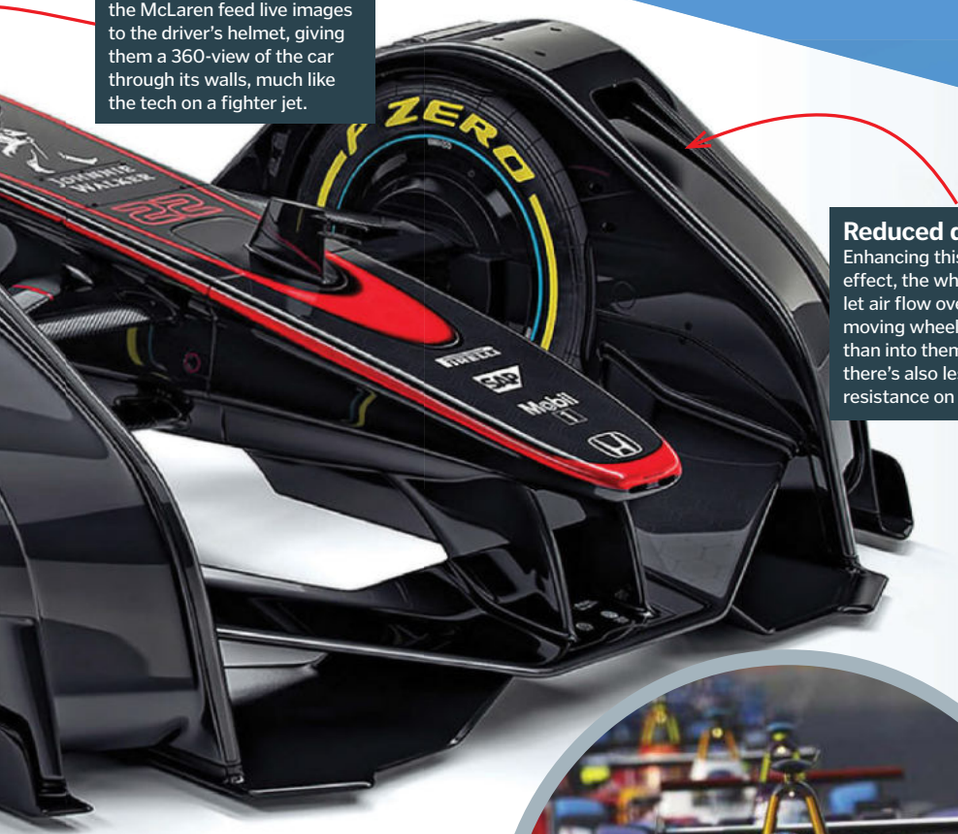
Enclosed cockpit
This keeps drivers safe from flying debris but the transparent top gives them the same uninterrupted views and allows spectators to see in.

Reduced height
The majority of the concept car's body is no taller than the wheels, meaning the car will enjoy an impressively low centre of gravity, ideal for fast cornering.

Hidden wheels
Wheels enclosed into the body help reduce drag, making the car slip through the air even faster.

360-degree view
Cameras positioned around the McLaren feed live images to the driver's helmet, giving them a 360-view of the car through its walls, much like the tech on a fighter jet.

Reduced drag
Enhancing this ground effect, the wheel guards let air flow over the moving wheels rather than into them, meaning there's also less air resistance on the car.



Formula E cars are so quiet that DJ sets often accompany the races

Noise: pollution or part of the experience?

The subject of noise creates something of a divide in motosport. For racing fans, the powerful roar coming from a car is all part of the experience, but there's a wider responsibility concerning noise pollution to consider (not to mention hearing damage). For the time being, it seems that fan experience is prevailing; after Formula 1 cars switched to turbocharging in 2015, there were mass complaints from spectators as to the flat sound of the new engines. Changes to exhaust pipe regulation for the 2016 season mean some of that signature barrage of sound has been recreated, though many fans remain unconvinced.

Over in Formula E, bosses contemplated running cars with fake engine noises to mask the uninspiring battery whine for spectators. This idea was later ditched, but whether fans will learn to love this eerily quiet motorsport as much as rowdy F1 remains to be seen.

Turbocharged engines have altered the characteristic roar of F1 races

Today's prototypes are advanced racers and their technology will soon be transferred to road cars

The race for evolution

Here's how the Le Mans race has helped develop the motoring world we know today

MILESTONE 1
1923 The first race
The inaugural Le Mans race was won by André Lagache and Réné Léonard for manufacturer Chenard et Walcker.

MILESTONE 2
1949 Alternative fuels
The Delettrez brothers became the first to compete in the race with a diesel car.

MILESTONE 3
1953 Disc brakes
British manufacturer Jaguar improved braking efficiency by installing disc brakes, and went on to take both first and second place.

MILESTONE 4
1967 Tyre 'slicks'
Michelin introduced the first 'slicks' – tyres that had a smooth tread for better grip on dry tracks.

MILESTONE 5
1974 Turbo engine
Porsche brought the first turbo engine to the Le Mans track, providing more power for the same amount of fuel – it won them the race.

MILESTONE 6
1998 Early hybrids
American Don Panoz designed a car with an electric motor as well as an engine, but it failed to qualify for the race.

MILESTONE 7
2006 Diesel triumph
The Audi R10 became the first diesel-powered car to win at Le Mans, racking up over 6,400 kilometres over the whole weekend.

MILESTONE 8
2012 Hybrid dominance
Just six years later, Audi once again broke a technological barrier, as its R18 e-tron car became the first hybrid winner.

MILESTONE 9
2016 Less fuel than ever
Porsche took home the trophy in 2016, using seven per cent less fuel per lap than the previous year in line with new regulations.

MILESTONE 10
2030 Pure electric racing?
As the hybrid class is pushed for ever-greener racing, you can expect prototypes to switch to fully electric powertrains within the next 15 years.

Le Mans: a test bed for tech

The world's most famous 24-hour race is the proving ground for next-gen car tech

Perhaps more than any other race on Earth, the 24 Hours of Le Mans has always been a proving ground for manufacturers piloting new technologies on cars. Taking the 'win on Sunday, sell on Monday' approach to its utmost level, manufacturers use the famous stage around La Sarthe to twin engineering ingenuity with salesroom success. This perpetual push for evolutionary technology in racing was borne from the race's tradition of allowing prototypes to compete, giving manufacturers a platform to try new technologies from a blank piece of paper rather than trying to shoehorn it into existing road cars. This has proved particularly fruitful in recent years, where Audi prototypes became the first race cars to win at Le Mans first with diesel and later with hybrid power.

From the lessons learned over 24 hours of racing, where cars and their technologies are pushed to their absolute maximum, manufacturers are able to fine tune developments that later appear in showrooms. For example, it is no coincidence that Audi, responsible for thousands of diesel cars on our roads, dominated the last decade at Le Mans with diesel racers, while both Porsche and Toyota, who race hybrids in the prototype LMP1 class, are also two of the biggest manufacturers of hybrid models.

Le Mans isn't just a proving ground for manufacturers. Tyre and fuel companies use the race for real-world research, with Michelin, for example, developing advanced tyre compounds that are long lasting and more environmentally friendly. If successful over the 24-hour period (meanwhile covering a distance of approximately 5,200 kilometres per car) the tyres are likely to be refined further for use on road-going supercars.

Windscreen wipers, as seen on this 1953 racer, were first piloted at Le Mans

Driver's perspective: Nick Tandy

The British pro racing driver for Porsche has enjoyed a long career in GT and top-level motorsport, winning some of the world's most famous races, including the 24 Hours of Le Mans and the 24 Hours of Daytona

Nick Tandy is one of Britain's most successful professional racing drivers

How tough is endurance racing on the driver today?
What many people don't realise is you have to be physically fit to drive a top-level motorsport car now. Whether it's Formula 1 or a Le Mans racer, the cars are so fast, have so much grip, and are capable of cornering at very high speeds. That means the forces acting on the car – and you – are extreme (we're talking several G at times), and you have to be fit to not only withstand those forces, especially on your neck, but maintain your concentration throughout to drive the car faster than anyone else. As such we have lots of physical training for endurance racing including core, back, stomach and general heart condition.

How has technology changed motor racing?
It's made cars faster, that's for sure, though in some areas the technology is actually restricted in the name of competition! It's also changed the role of the driver; for example, we no longer change gears using a conventional 'H' pattern manual gear shifter, like you see in some road-going cars today. Instead, we change gears by simply pulling a paddle mounted behind the steering wheel column, which is far easier. The way electronics control the car now might sound boring but you can play around with the parameters more, so it's more exciting. Technology has also made racing safer, don't forget. In the 1960s and 1970s, racing was notorious for incidents and crashes, often fatal. It's a lot different today. Don't get me wrong, drivers still fully understand and accept when they're climbing into a car that motorsport can be dangerous, but there are much better safety systems in place today to prevent injury or worse. The car talks to you now: you can see from various displays exactly how healthy the engine and tyres are, which takes away all our excuses too if we have an 'off' day!

> "Technology has made the gap between a good and a great driver much more noticeable"

Tandy believes technology has given racing drivers more to do, but the sport is now more exciting for spectators

Has this increase in technology made your job easier?
From a driving point of view it's harder as there's more going on, but that's made the gap between a good and a great driver much bigger and more noticeable. It's no longer about merely jumping in a car and driving it fast. It's about learning the car's complex systems to get the best out of it. In the 24 Hours of Le Mans with the prototype cars, you can only use a certain amount of energy per lap on average, so you can't just go completely flat out, you have to find a balance. One aspect that's definitely helped, though, is driving simulators. They're now so good and so realistic that we'll book in hours of time in them prior to races to learn tracks if we've never raced there before. We also use driving simulators to improve our driving style and, in some cases, try out different setups on the car. Without those it would all be down to guesswork once we arrive at a circuit.

What do you think the future of racing is going to be like?
I don't think we'll see fully electric cars in the WEC [World Endurance Championship] but more hybridisation, that's for sure. It'll be faster, more competitive, and more thrilling for fans. Cars are getting more reliable, so we'll see less retirements during the race, and some people are worried that adding more technology will only interfere, but I think the opposite – it's only going to make motorsport, of any discipline, more exciting for everyone.

Indy 500: the world's best race?

This Stateside fixture boasts more than 100 years of evolution

You may think there's not much that can be garnered from cars driving around a four-kilometre long oval, but the famous Indianapolis 500 race – more commonly known as the Indy 500 – has more than a century of racing to its name and has borne witness to some striking innovations in motoring.

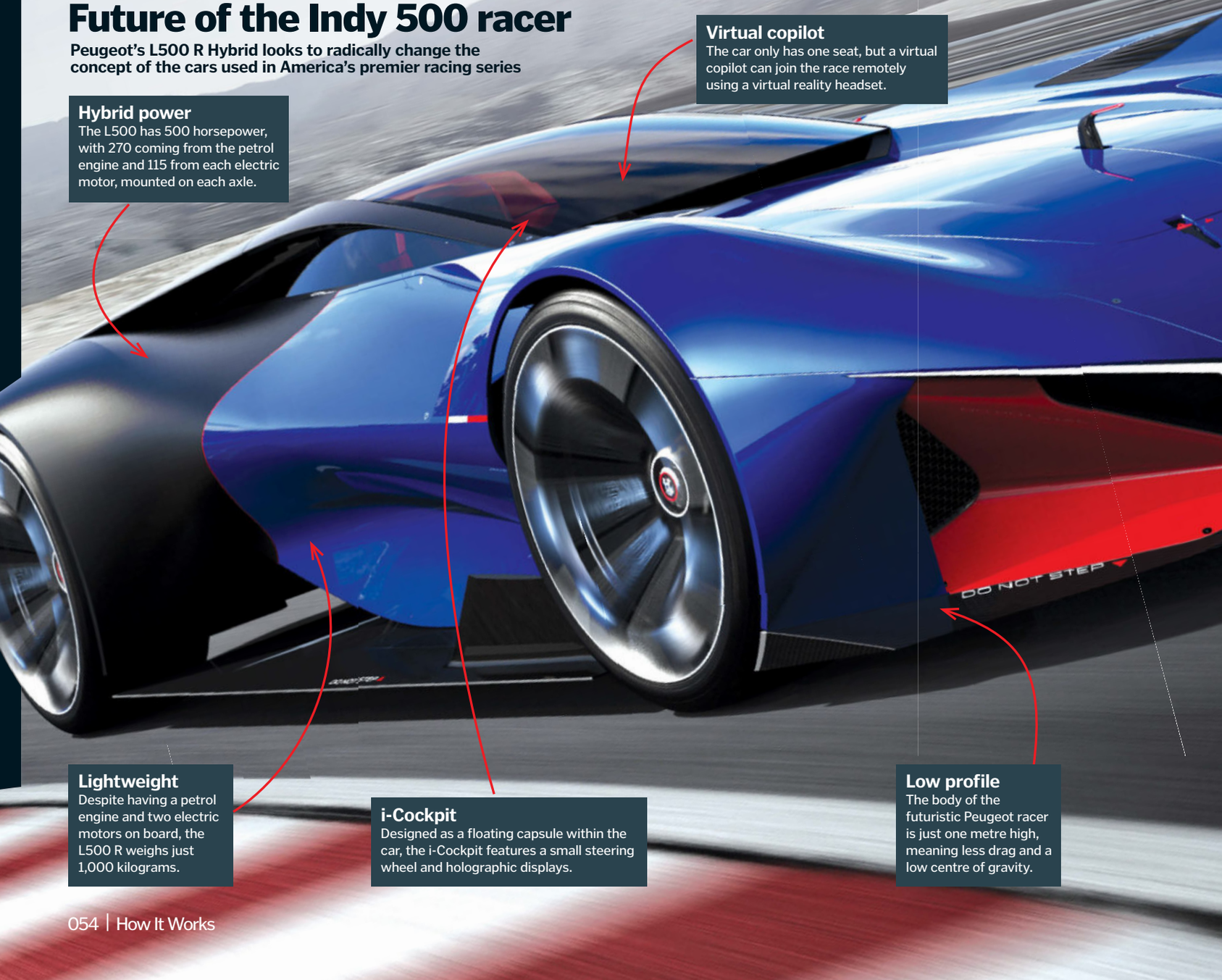
The whole thesis of the Indy 500 circuit was for research. After building the track in 1908, joint owner Carl G Fisher invited manufacturers to test top speeds along the back straight of the venue. By 1911 the famous Indy 500 race was born, in which competitors have to complete 200 laps of the oval track in the fastest time – a distance of 800 kilometres, or 500 miles, the latter giving the race its name. Technological innovations began almost immediately; the race is credited with piloting the first rear-view mirrors in 1911, while the 1920s saw cars – including both privateers and manufacturers such as Fiat, Buick and Mercedes – experiment with supercharging and even four-wheel-drive.

As the years rolled on, the performance of cars improved but also their fuel economy too. The first driver to finish the entire race without a fuel stop was stuntman Cliff Bergere in 1941, despite regulations only permitting smaller engines and fuel tanks than previous years. In 1952, the first race car with a turbocharger was designed, taking inspiration from World War II aircraft, and the 1970s saw inverted wings being added for increased downforce. However, this push for evolution has not come without cost: there have been over 50 motoring-related fatalities at the Indy 500 event to date, which is markedly more than any other race.

Today, though, the Indy 500 competitors look much like those of a Formula 1 event, albeit with bigger engines.

Future of the Indy 500 racer

Peugeot's L500 R Hybrid looks to radically change the concept of the cars used in America's premier racing series



Virtual copilot
The car only has one seat, but a virtual copilot can join the race remotely using a virtual reality headset.

Hybrid power
The L500 has 500 horsepower, with 270 coming from the petrol engine and 115 from each electric motor, mounted on each axle.

Lightweight
Despite having a petrol engine and two electric motors on board, the L500 R weighs just 1,000 kilograms.

i-Cockpit
Designed as a floating capsule within the car, the i-Cockpit features a small steering wheel and holographic displays.

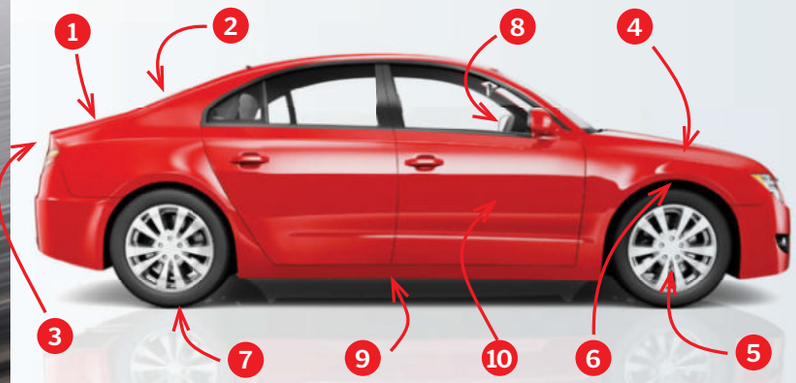
Low profile
The body of the futuristic Peugeot racer is just one metre high, meaning less drag and a low centre of gravity.

Is Peugeot's L500 R Hybrid the future of racing?

The L500 R Hybrid takes just 19 seconds to cover 1,000m from standstill

From racetrack to road

Ten consumer car technologies that made their name in motorsports



1 Drag Reduction System
F1 cars have adjustable flaps on their rear wings to reduce drag and give a pursuing driver a better chance of overtaking. Many hypercars such as the Porsche 918 and McLaren P1 employ the same tech today.

2 Aerodynamics
Cars are now designed to be more streamlined to cut through the air with less drag, a technique first used on slimline F1 cars.

3 Downforce
Rear wings commonly seen on F1 cars started finding their way onto road cars in the 1970s, improving the grip on the road at high speeds.

4 Hybrid power
Engines can now work in harmony with electric power units, technology originally piloted in endurance racers.

5 Energy recovery
Hybrid and electric vehicles recuperate energy from braking, just like Le Mans racers.

6 Active suspension
Suspensions now have active damping to deal with different terrain and provide a smoother ride.

7 Tyres
Tyres now provide better grip under hot conditions and at great speeds, thanks to developments for racing cars. They're also more streamlined, producing less drag.

8 Push ignition
Many modern cars are replacing the classic key-turning ignition with a push button, inspired by race cars that use them to shave precious seconds off start times.

9 Carbon fibre
F1 cars are made almost entirely from carbon fibre. Sports cars now feature carbon-fibre bodywork too, as it is both light and highly durable.

10 Transmission
Semi-automatic gearboxes were first used on race cars in the 1970s and are a common fixture in sports cars today.

Hybrid technology is becoming more commonplace in sports cars, family saloons and even SUVs

Even the humble rear wing, found on high performance sports cars today, was first debuted on the track back in the 1960s

Breakdown trucks

From a flat tyre to an upturned vehicle, here's how they tow you to safety

Breakdown trucks are often called when the weather is at its worst

It was the early 1900s and a US mechanic was tasked with pulling an upturned car out of a creek. Ernest Homes gathered ropes, blocks and a team of men and eight hours later, he was inspired to build the first breakdown truck – a Cadillac fitted with a crane and pulley system.

Today, the simplest tow trucks still bear some resemblance to his invention. They feature a flatbed that can be tilted and slid to reach road level, and an electric winch to pull your car up the ramp and onto the truck. The wheels are then clamped securely in place with ratchet-style compression straps. Larger vehicles that won't fit on a flatbed can be recovered with a 'spectacle lift' truck. This is a more compact tow truck with a hydraulic boom on the back. The front wheels of the stricken vehicle nestle in the boom's rectangular supports, which look like the frames of a pair of spectacles, hence the name.

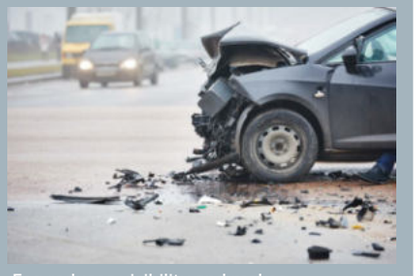
When a vehicle has been involved in an accident, it may require craning back onto the road or levering back upright first. The most versatile breakdown trucks have L-shaped boom arms that can be slid underneath a wreck and used to lift it clear. Breakdown trucks need large engines to cope with their towing load, but they are also engineered to be as light as possible, without compromising strength.

"Breakdown trucks need large engines to cope with their towing load"

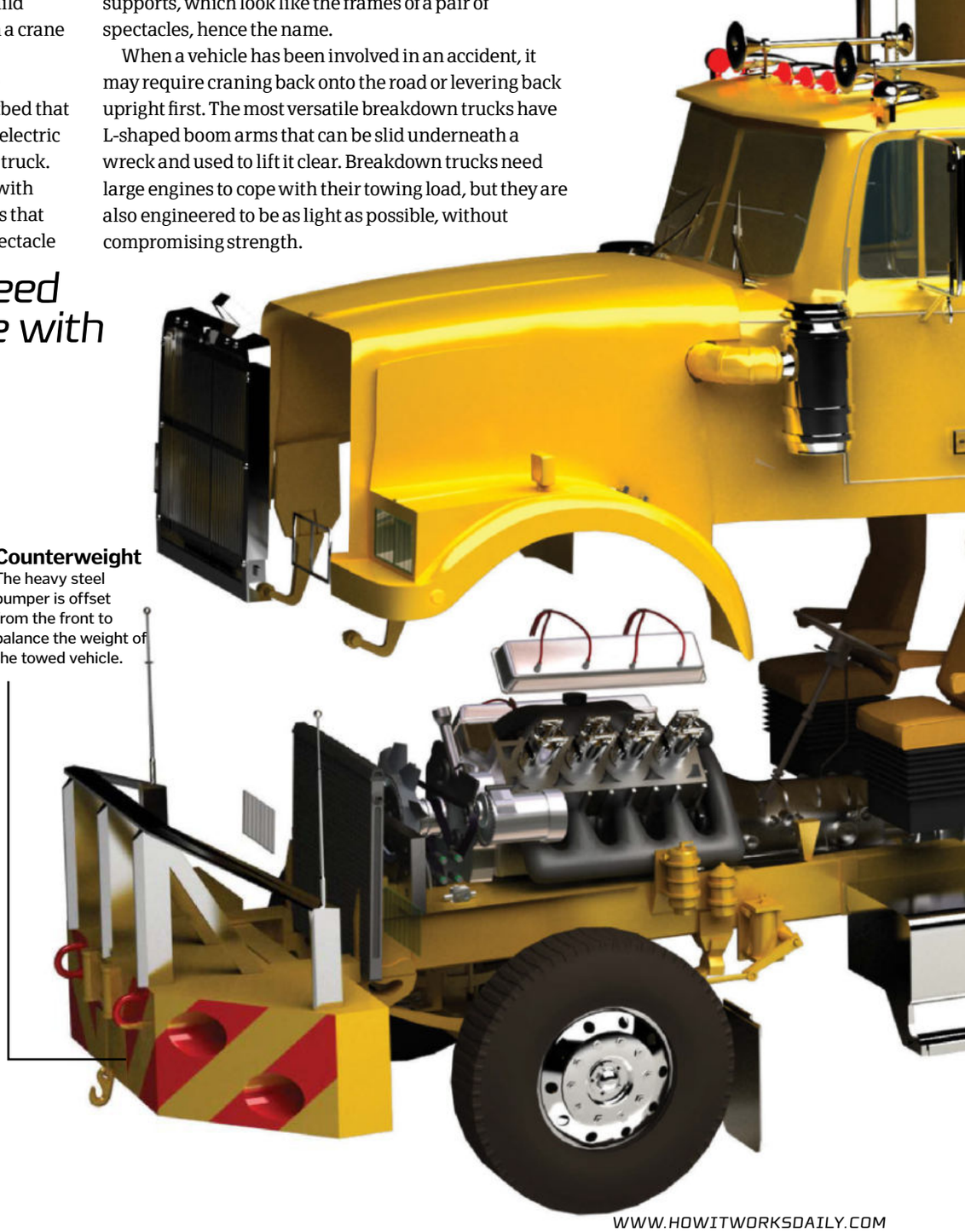
The £600,000 pile-up

The single biggest roadside recovery operation in the UK occurred in 2013 on the Sheppey Crossing in Kent. At 7:15am on 5 September, vehicles collided in heavy fog and triggered a cascade of further crashes that continued for ten minutes. Although no one was killed, there were eight serious injuries and 35 more that required hospital treatment. In total, more than 130 vehicles were involved in the pile-up, which blocked the bridge on all four lanes in both directions. It took nine hours and a fleet of tow trucks to clear all of the wrecks.

A similar 100-vehicle pile-up occurred in the US in 2012, on a foggy motorway in Texas. Two people died on that occasion, with another 58 injuries. Fog is responsible for some of the largest multiple pile-ups because drivers cannot see that the traffic ahead is stationary until it is too late.



Fog reduces visibility and makes crashes more likely



Counterweight
The heavy steel bumper is offset from the front to balance the weight of the towed vehicle.

Ready to recover

Modern tow trucks are equipped to handle the trickiest breakdowns

Electric winch
Low gear ratios provide very high torque to pull heavy vehicles back up steep embankments.

Hydraulic jacks
Driven by a compressor powered by the truck engine, these supply the lifting force for the boom.

L-shaped boom
The end section can be used like a forklift, to help upright vehicles that are lying on their sides.

Hook
This is used to tow vehicles out of ditches or pull an upside-down vehicle onto its side.

Wheel restraints
These can be folded out to support the front wheels of the broken down vehicle.

Toolbox
All the tools needed to handle the most common roadside repairs are stored here.

Air hose
A separate compressor supplies air to re-inflate flat tyres.

Control box
This is used to operate the winch and hydraulic boom. Some controls are also duplicated inside the truck cab.

Rear wheels
A large tyre area and multiple axles help to spread the load of heavy vehicles during towing.

Turboprop engines

Inside the propulsion system that gets low-speed aircraft off the ground

A normal jet engine (often called a turbojet) uses fan blades in order to compress air pulled in at the front, and then adds fuel and ignites it. Some of the exhaust energy is used to keep the compressor fan turning, but most of it is expelled at the rear to produce thrust.

A turboprop engine turns this on its head; almost all of the energy is harnessed to turn the propeller shaft at the front, and only about ten per cent of the thrust comes from the exhaust gas. The propellers are much larger than the diameter of the jet engine, so most of the air they push flows past, rather than through it.

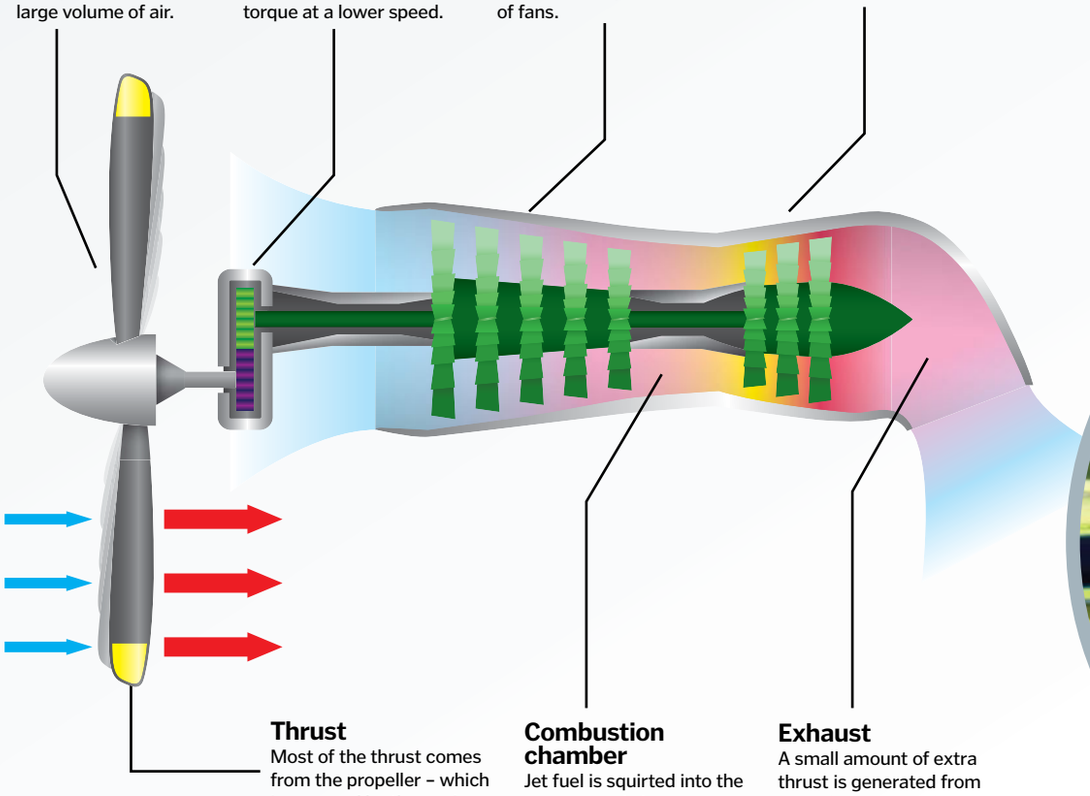
Turboprop air intakes are much smaller than the propeller diameter

This is more efficient at lower speeds, because the engine only adds fuel to the small proportion of the airflow that generates thrust.

Turboprops are slower than jet engines but cheaper to run. They are mostly used in short-hop commuter planes. A helicopter engine is also a kind of turboprop (called a turboshaft) where the rotor blades are driven through a more complicated transmission system.

Inside a turboprop

How does the jet engine turn the propeller?

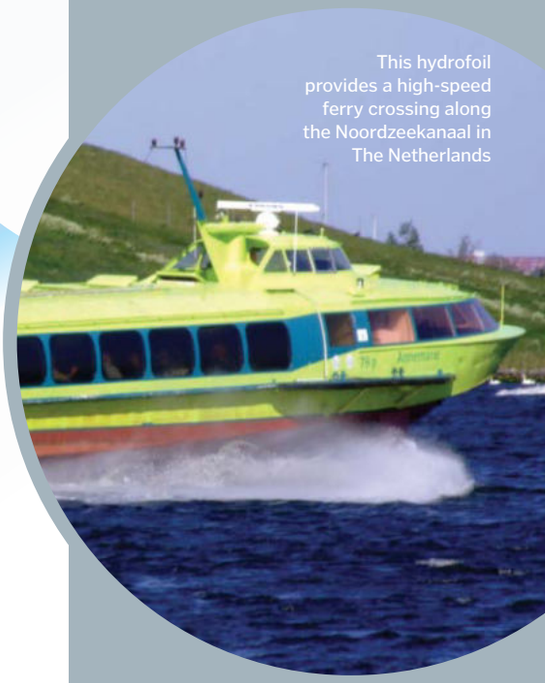


Hydrofoils

Is it a boat? Is it a plane? It's actually a bit of both

A hydrofoil is a wing that flies through water instead of air. As water is 1,000 times denser than air, it generates a lot more lift for a given speed. A boat equipped with these wings begins each journey floating in the water like an ordinary vessel. As it picks up speed, the hydrofoil lifts it further out of the water until the hull is completely clear. This hugely reduces the drag through the water, making it at least twice as efficient as a boat that just skims on the surface.

Hydrofoils have two basic designs. The simplest is a surface-piercing hydrofoil, which uses wings arranged like a giant V under the boat. As the boat picks up speed, more and more of the hydrofoil lifts out of the water until the lift balances the weight, so this design is self-stabilising. The alternative design, known as a fully submerged hydrofoil, is less affected by waves, but it needs to control its flying height by constantly adjusting the angle of the hydrofoils in the water. Hydrofoils generally don't perform well in rough seas, so they are mostly used on lakes and rivers.



This hydrofoil provides a high-speed ferry crossing along the Noordzeekanaal in The Netherlands

TOP 20 FACTS ABOUT APES

Get to know your closest animal relatives

Apes are not monkeys

Although they are both primates, the last common ancestor of apes and monkeys lived around 25 million years ago. Apes are generally larger, they don't have the tails that monkeys do, have a larger brain-to-body size ratio, and rely more on their eyesight than sense of smell. Apes also have more intricate social structures and longer lifespans.

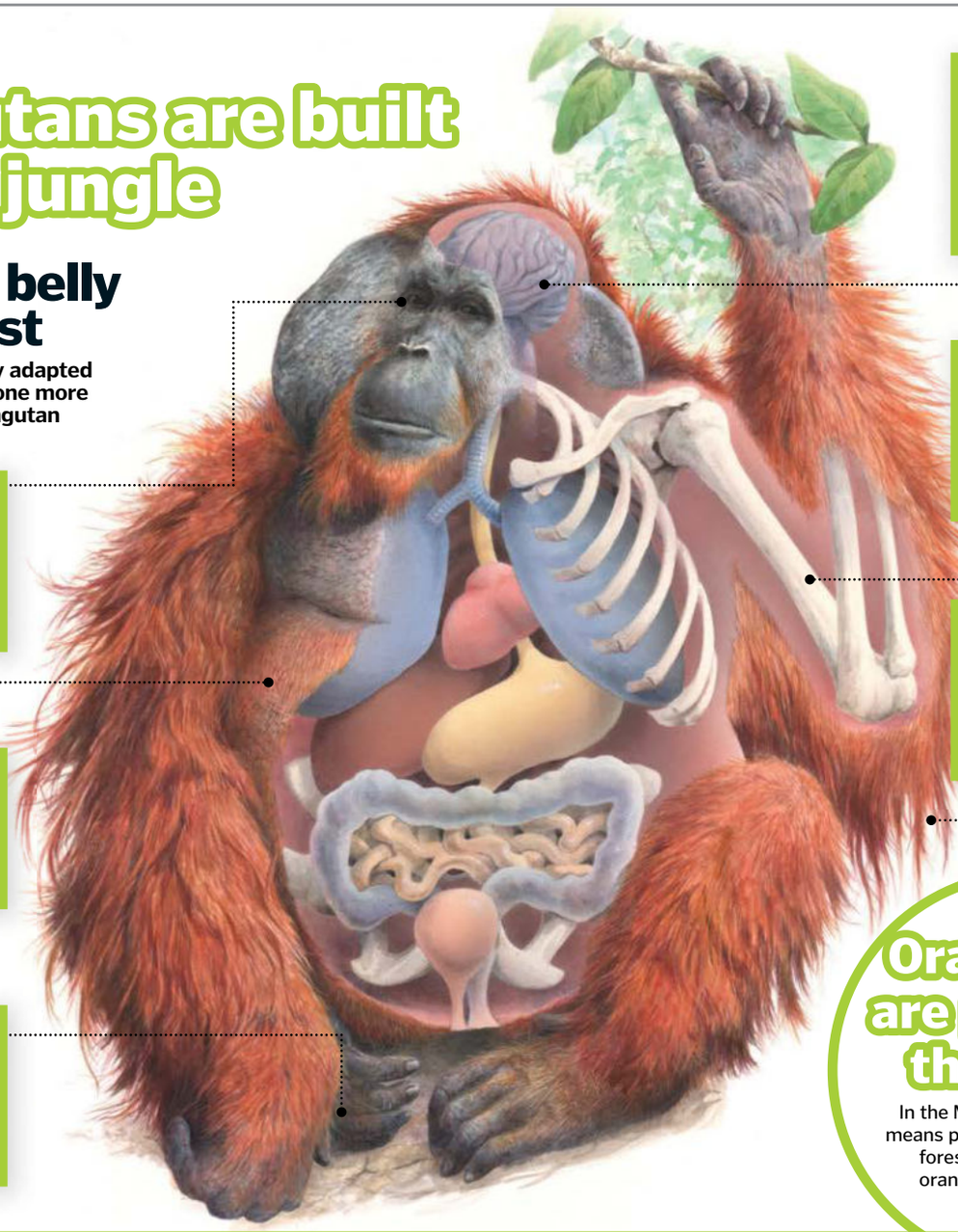
Bonobos are rare

Bonobos are one of the most rare primate species, only found in the lush rainforests of the Democratic Republic of Congo. There are thought to be less than 100,000 individuals left in the wild, spread across just a handful of populations.

Orangutans are built for the jungle

Inside the belly of the beast

Great apes are perfectly adapted to their environment, none more so than the mighty orangutan



Brain
Orangutans have a larger cerebellum than humans – the part of the brain that controls posture and movement – helping them to move from tree to tree.

Arms and legs
Very long arms and legs, with a strong set of muscles, allow for perfect swinging movements through the trees.

Hair
The long, coarse hair of the Sumatran orangutan is thinner than the Bornean species as an adaptation to the climate.

Eyesight
Forward-facing eyes provide orangutans with keen binocular vision for accurately gauging depth and distance.

Size
A male orangutan can reach 1.5m tall and weigh 120kg. Females are smaller, at around 1.2m and 45kg.

Fingers and toes
Just like humans, orangutans have four fingers and an opposable thumb. They have the same on their feet.

Orangutans are people of the forest

In the Malay language, 'orang' means person and 'hutan' means forest. This describes the orangutan perfectly in its

Apes have feelings too

Given that we share so much DNA with the great apes, it's no surprise that they show many human-like traits. One of the most impressive of these is their emotional intelligence. Although it's very easy to project human emotions onto animals, many experts maintain that the great apes are capable of showing and reading emotions in a human-like manner.

Chimpanzees display behaviour that correlates with a complex array of emotions, including joy, affection, compassion, empathy, fear, despair and anger. One study filmed chimps in captivity, as one of their family members was terminally ill. The chimps showed incredibly tender responses to the ill animal, and then grief-like behaviour after she had passed away. In the wild, chimpanzees have also been known to fall into mass panic when one of their own is hurt or killed.

Studies on bonobos have shown that these apes learn to regulate their emotions in a similar way that human children do, by taking social cues from their superiors. In the test, two groups were observed – bonobos that had been raised by parents, and a group of orphans. The parent-raised apes were able to move on from squabbles quickly, while the orphans were distressed for a while afterwards. The mothered apes also appeared to show more empathy to others involved in bust-ups, with plenty of hugs and grooming.

Chimps and bonobos are also rather prone to temper tantrums, pouting, whimpering, scratching and banging to show their distaste when things don't go their way.

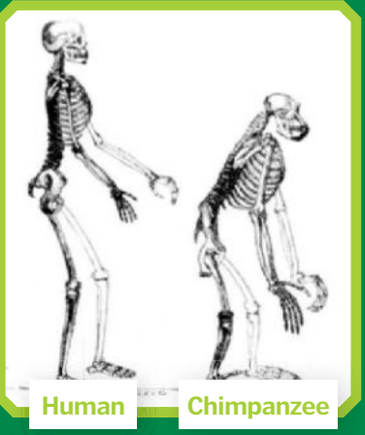
Although not as strong as the emotions displayed by chimps and bonobos, gorillas and orangutans are by no means exempt from showing their feelings in a similar way. Amazingly, it is even possible that apes are able to read human emotions from our facial expressions.

Gorillas have been witnessed grieving for their young when they die

We share 99+ per cent of our DNA with chimps

Gorillas, chimpanzees, bonobos, orangutans and humans all belong to the family of primates called Hominidae. Based on genetic analysis, humans are more closely related to chimpanzees and bonobos, both sharing 99.6 per cent of our DNA. Gorillas share 98 per cent and orangutans share 97 per cent. However, although the similarities are striking, it's that 0.4 per cent that has allowed us to advance so far past the evolution of the apes (bear in mind that we share almost 50 per cent of our DNA with fruit flies!)

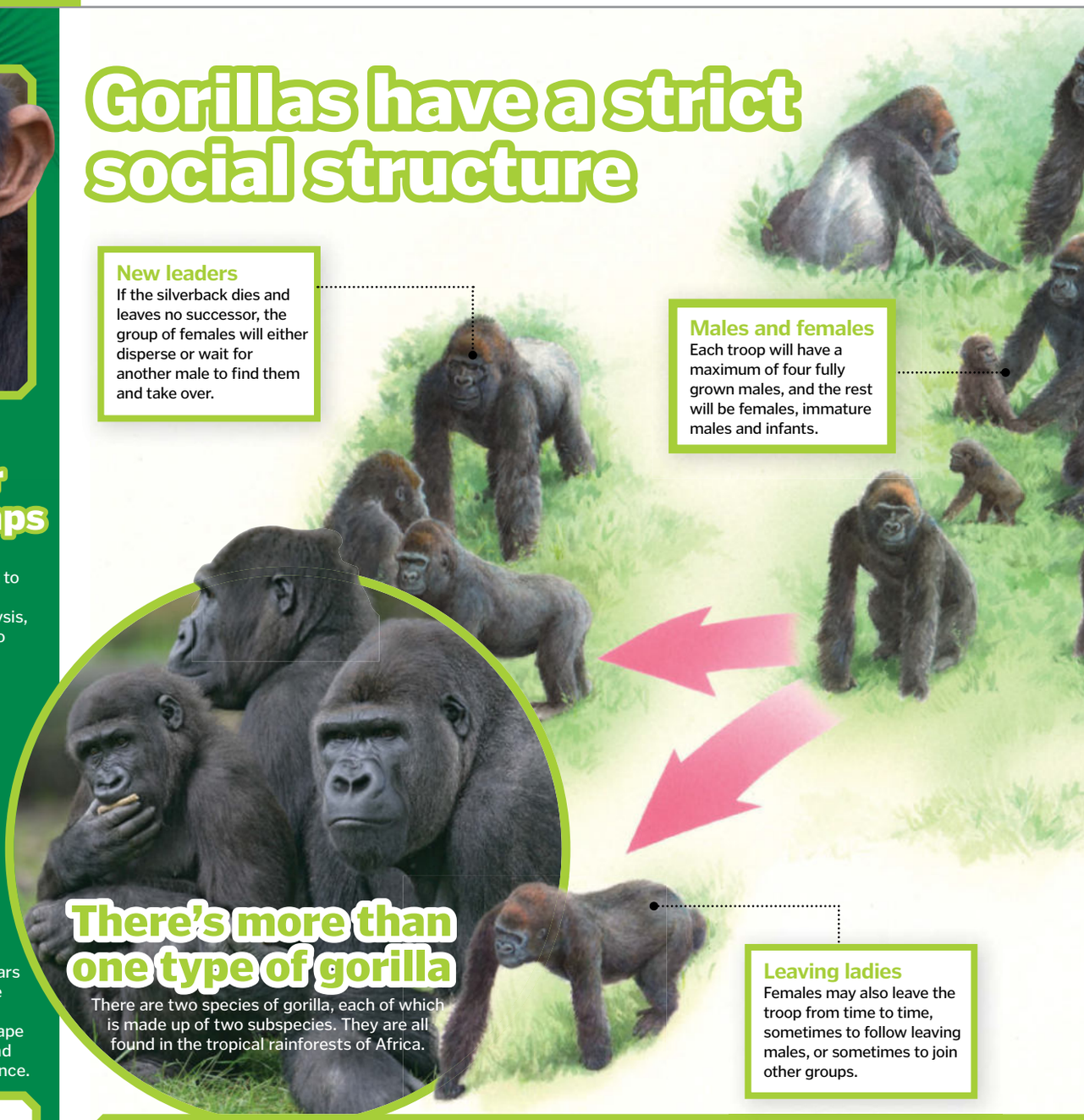
Humans aren't descended from any primate species that are still alive today. The common ancestor of chimps, humans and gorillas evolved around ten million years ago. At around six million years ago the lineage broke off that gave rise to modern humans and chimpanzees. Our closest African ape relatives were in the genus Pan, and likely looked chimp-like in appearance.



Apes have their own language

The great apes are a vocal bunch, and use a large vocabulary of sounds to communicate, including shrieks, hoots, roars and growls, as well as other more subtle noises.

Gorillas have a strict social structure



New leaders

If the silverback dies and leaves no successor, the group of females will either disperse or wait for another male to find them and take over.

Males and females

Each troop will have a maximum of four fully grown males, and the rest will be females, immature males and infants.

Leaving ladies

Females may also leave the troop from time to time, sometimes to follow leaving males, or sometimes to join other groups.

There's more than one type of gorilla

There are two species of gorilla, each of which is made up of two subspecies. They are all found in the tropical rainforests of Africa.

Gorillas grin like us, but it's not because they're happy

Similar to the way we tell how fellow humans are feeling by assessing facial expressions, gorillas use an array of expressions to communicate with one another, along with gestures and vocalisations. One of the most easily recognised is the 'play face'. This involves an open mouth but covered teeth; it's non-threatening and means 'I could bite you but I won't'. Another is similar to the human smile, where all teeth are on show. We associate smiles with enjoyment, but this is a greeting or affiliation. Similarly, it's often thought that when teeth are bared, this signifies aggression, but with gorillas this is only true if the mouth is open and ready to bite. If the teeth are pressed together, this is almost always a sign of submission. These expressions are combined with many other physical clues and vocal expressions to form a complex language.

All over the face

Different facial expressions in gorillas are a key communicative tool in the troop

Fear

An open mouth and a tilted head can signify that the gorilla is afraid. It is often accompanied by a scream to inform others it is time to flee.

Silverback male
A dominant silverback male protects his troop and defends from outsiders. He might also have a 'second in command'.

Adult males
When the males in the troop mature, they leave to form bachelor groups, or form their own individual troops.

Troops
Gorillas live in groups known as troops, with numbers ranging from two to 30 individuals.

Female hierarchy
The females will jostle for proximity to the silverback. Their hierarchy is based upon their length of time in the troop.

Leadership challenge
The oldest and strongest male is usually dominant, and sometimes his position is challenged by newcomers or maturing males.

Apes always make their beds

All great apes sleep in nests and show sophisticated building techniques, using the differing way that sticks and twigs snap and bend to build comfy sleeping dens. Apes make a new nest every night, as they rarely sleep in the same place twice. Silverback gorillas always make nests on the ground, but females and younger males prefer to sleep aloft. Orangutans, chimps and bonobos show the same building capabilities, choosing large forks in strong branches to build a nest that can support their weight, and then padding the nest out with smaller twigs and leaves for comfort. In a lifetime, a chimpanzee may construct over 19,000 nests!

An orangutan and baby rest in their nest

Orangutans are slow breeders

Orangutans are the slowest apes to reproduce; they live up to 45 years in the wild and have a baby every eight years. The young depend on their mothers for over five years.

Brain size isn't everything

Gorillas are larger than humans but their brains are smaller – it's energetically expensive to keep a big brain running, so a smaller brain size is an evolutionary trade off.

Chest beat
Males beat their chests with the flat of their palms to show off their magnificence to others! It's the ultimate display of male pride.

Full play face
When half of the teeth are exposed this is a full-play face. It signifies where gorillas are involved in more intense and prolonged bouts of play.

Distress
Pursed lips and raised eyebrows can signify the gorilla is unsure or distressed. This type of expression is often displayed by babies if they're left alone.

Play face
An open mouth and covered teeth signifies that gorillas of all ages are ready to play. It's a gesture that says: "let's have some fun."

Seduction
An open stance, accompanied by bristling hair and a swagger or strut to the walk, is a sign of a male trying to catch the ladies' attention.

Apes are the sharpest tools in the box

The use of tools has long been considered a mark of intelligence, and the great apes are some of the canniest tool wielders out there. Tools can be loosely defined as items that apes use to achieve a task. These can be 'naturefacts' – items that are used as they are found – or they can be 'artefacts', which involve some form of modification. For example, chimps will sometimes chew on sticks before poking them into termite mounds.

Different great ape species show differing levels of tool use, with the chimpanzees coming out on top for the most ingenious uses and modifications. Gorillas and orangutans use tools habitually; for example, gorillas have been known to use sticks for support, or to lay down items to walk over muddy ground. Orangutans use sticks in order to scratch themselves and extract seeds, and even fashion novel leaf-ponchos. Bonobos on the other hand, despite living in similar environments where there are many tools available, don't favour using these objects as much.

It was once thought that this behaviour was socially learnt; that youngsters would see the elder members of the troop using tools and take on these skills. New research has shown that this behaviour appears to be innate. We also thought that some apes learned to use tools by copying nearby humans, but the discovery of rudimentary tools from a 4,300-year-old chimpanzee settlement on the Ivory Coast suggests otherwise. These stone hammers were too large for any human to use, and bore residues of nuts and seeds that chimps love to eat.

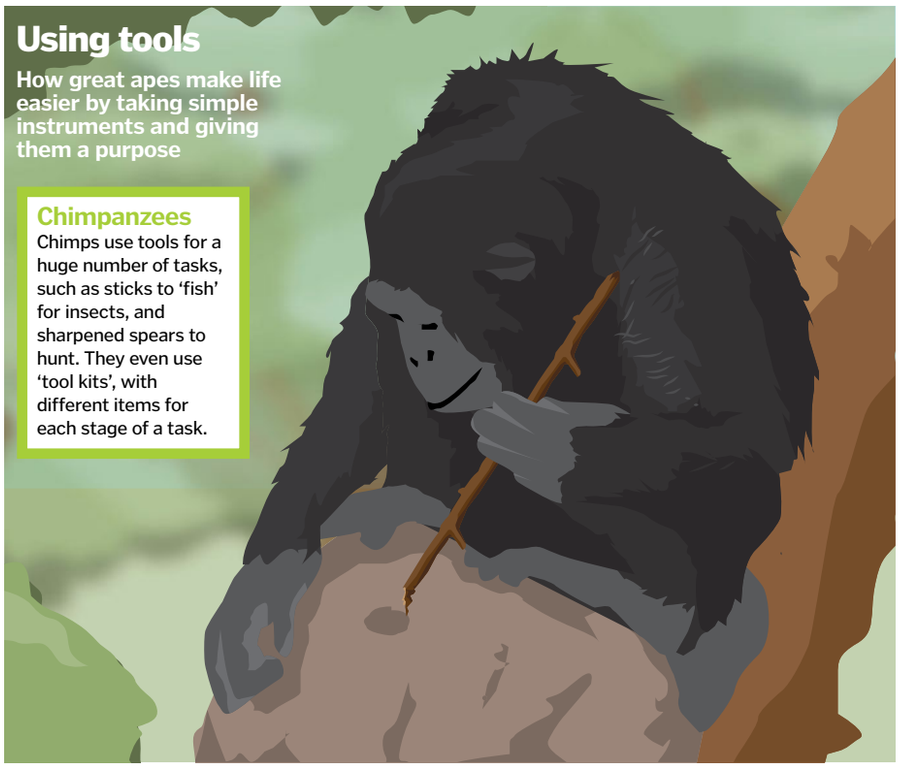
Tool use appears to vary in differing ape communities in different regions. It's also much more prevalent in apes in captivity. Captive ape populations are presented with a set of very different challenges, so with more time to experiment, this may spur them on to develop new tools!

Female bonobos rule society

Bonobos, unlike the rest of their great ape cousins, live in a matriarchal society. The females are the dominant sex; they are able to (peacefully) overpower the males to choose their own mates and claim the best food.

Using tools

How great apes make life easier by taking simple instruments and giving them a purpose

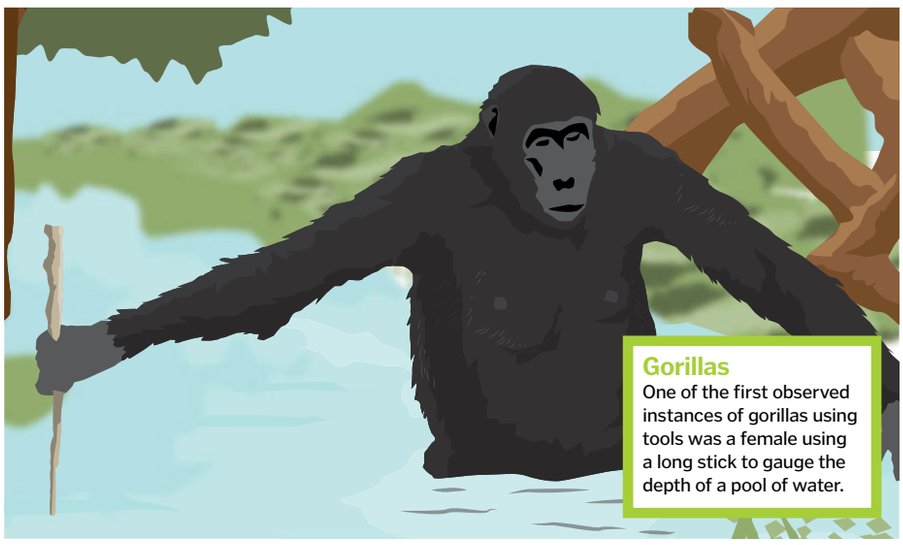


Chimpanzees

Chimps use tools for a huge number of tasks, such as sticks to 'fish' for insects, and sharpened spears to hunt. They even use 'tool kits', with different items for each stage of a task.

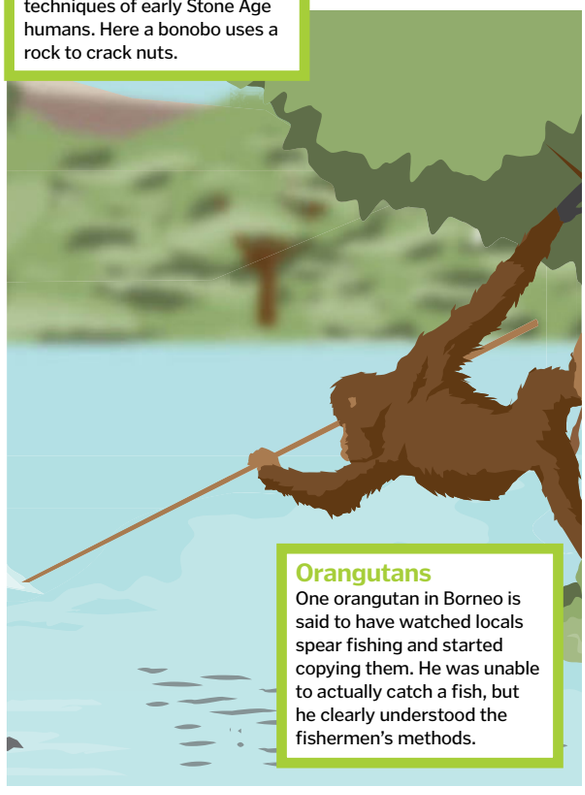
Bonobos

While not huge tool fans in the wild, captive bonobos are described as having the foraging techniques of early Stone Age humans. Here a bonobo uses a rock to crack nuts.



Gorillas

One of the first observed instances of gorillas using tools was a female using a long stick to gauge the depth of a pool of water.



Orangutans

One orangutan in Borneo is said to have watched locals spear fishing and started copying them. He was unable to actually catch a fish, but he clearly understood the fishermen's methods.

Some apes are great at maths

We have covered the great apes' incredible use of tools that shows some truly outstanding and undeniable brainpower. But aside from this ability, just how clever are they? The answer is: very.

Apes will never be able to speak because of the position of their larynxes, but that doesn't mean they don't understand language. A gorilla named Koko learnt a vocabulary of more than 1,000 words in American sign language and can use it to communicate. A bonobo called Kanzi even learnt to understand some spoken English the way that human children do, by being exposed to it from an early age. There are also orangutans that are maths wizards, chimpanzees that have beaten their human trainers at memory games, and bonobos that can drum along to a beat. And that's just scratching the surface of what great apes can do.

Just like in humans, cognitive abilities differ from one ape to the next. And in yet another parallel with us, it seems that this is in part due to their genes and in part due to their social structure and environmental influences: it's the age-old nature/nurture debate.

Kanzi the bonobo at the Great Ape Trust in Iowa, US, has been taught other skills such as building fires and cooking food

Bonobos make love, not war

Bonobos have a reputation for being a curiously peaceful and cooperative species, especially when compared to their rowdy cousins, chimpanzees. Where chimps will aggressively fight one another, there's never been a recorded case of a bonobo killing another bonobo. They rarely fight, choosing instead to resolve any conflict with sexual behaviour. A study in 2013 attributed their laid-back lifestyle to the heightened presence of a key thyroid hormone later in life, whereas in humans and chimps, the relative levels decrease after puberty.

Once thought to be 'pygmy' chimpanzee subspecies, the bonobo species wasn't fully recognised until 1929

Apes are under threat

The forest habitats of great apes in both Africa and Asia are rapidly decreasing due to logging, mining and farming. This is just one of the issues threatening ape survival.

They're rainforest gardeners

As the world's largest tree-climbing species, orangutans disperse seeds from their favourite foods, and help to maintain the health of the ecosystem for other forest inhabitants.

Orangutans: flanged or unflanged?

Male orangutans can develop large facial pads known as flanges, but it's not fully known why some males develop these and others don't.

Ocean currents explained

The conveyor belt that keeps the oceans healthy

When ice forms off the coast of Antarctica, the seawater around it gets saltier because the water freezes first, leaving the salt behind. The extra salt makes the remaining seawater denser, so it sinks down the side of the continental shelf and spreads slowly along the ocean floor.

The sinking water has to be replaced from somewhere, so this creates a surface current that pulls warmer water in from the north. This is called thermohaline circulation (from the Greek for temperature and salt), and it is the main force behind the deep ocean currents. But at the surface, the Sun's heat causes winds, and these create a different set of much shallower currents. The Earth's rotation twists these into circling currents called 'gyres', which rotate clockwise in the Northern Hemisphere and anticlockwise in the Southern Hemisphere.

Currents are vital to the ocean's ecosystems. Most marine life is found near the surface, where it would quickly run out of nutrients were it not for currents sweeping up fresh supplies from the sea floor. At the same time, downward currents supply vital oxygen-rich water to the inhabitants of the deep sea.

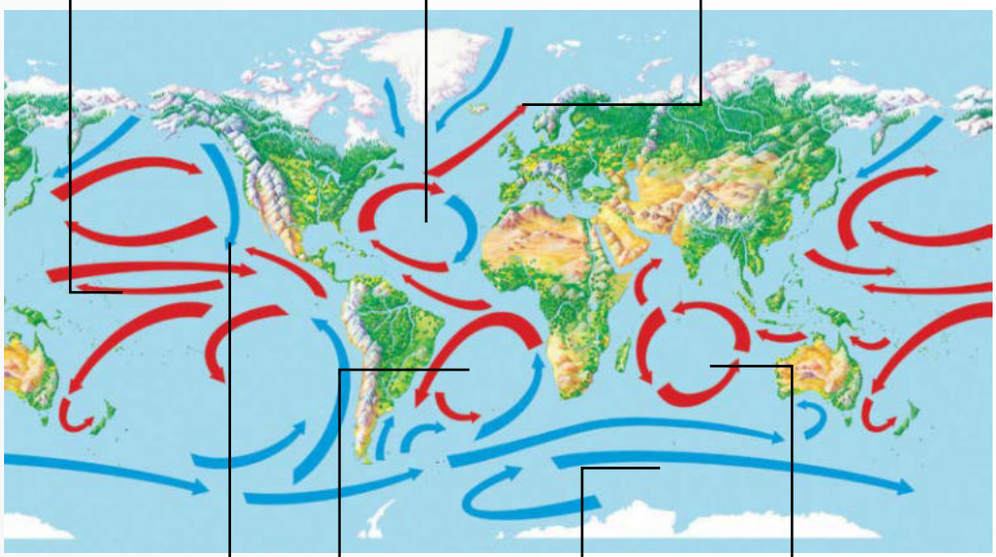
Current affairs

Earth's ocean currents are all connected in a series of swirling eddies

Equatorial currents
The North and South Equatorial Currents carry warm waters westward, while the Equatorial Counter Currents return some warm waters eastward.

Gulf Stream
The Gulf Stream brings warm water from the Caribbean towards western Europe. The Canary Current circulates cold water back again.

Norwegian Current
Warm water breaks away from the Gulf Stream, pushing cold water back, past Greenland.

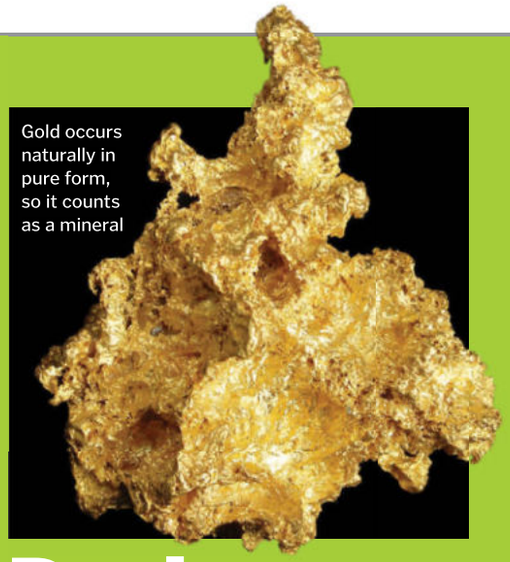


California Current
The cold water from northwestern Canada brings the characteristic coastal fog to California's coastline.

Benguela Current
Cold water flows north past South Africa, warms and returns as the Brazil Current.

Antarctic Circumpolar Current
This is the dominating current in the Southern Ocean, circling the continent of Antarctica from west to east. It creates some of the roughest seas on Earth.

South Indian Current
This flows north from the Antarctic Circumpolar to connect to the West Australian current.



Gold occurs naturally in pure form, so it counts as a mineral

Rocks, minerals and elements

Why is quartz a mineral but granite a rock?

Elements are the different kinds of atoms that make up ordinary matter. Each element is composed of atoms with a precise number of protons in their nucleuses. Iron atoms have 26 protons for example, and a lump of pure iron will consist entirely of atoms with this structure. Different elements can react with each other to form compounds, and some of these form crystals, where the atoms are arranged in a regular, repeating lattice.

Minerals are solid, naturally occurring crystals, which are inorganic (they are not made by living things). Salt is a mineral because it consists of a regular grid of sodium and chlorine atoms stacked together. But sugar isn't a mineral; although it has a crystal structure, it is an organic substance, because plants make it.

Rocks are a mixture of one or more minerals, locked together to form a hard solid. For instance, granite is a rock that is composed mainly of the minerals quartz and feldspar. Instead of having chemical formulae like minerals, rocks are classified into three different types, depending on how they form: igneous, sedimentary or metamorphic. Igneous rocks form from cooling magma, sedimentary rocks are formed by sediment accumulating over time, and metamorphic rocks are formed when these two types are changed due to high temperature or pressure.

Life cycle of a gentoo penguin

Among the coastal rocks of the Antarctic, you'll hear the patter of tiny orange feet

Waddling across the rocks of the Antarctic Peninsula, gentoo penguins gather for the annual breeding season. They undertake this springtime ritual from the age of three onwards, usually with the same partner. Loyal and nurturing, these sea birds form lasting bonds and never venture far from the breeding ground all year round, unlike other penguin species that migrate.

The adults share the parenting duties, taking it in turns to incubate the eggs and guard the chicks while the other hunts for fish, squid and krill. They can dive as deep as 200 metres and slow their heart rate from 80-100 beats per minute (bpm) to just 20bpm to remain underwater for up to seven minutes. Their streamlined, torpedo-shaped body propels them through the water at 36 kilometres per hour – faster than any other penguin.

This unrivalled speed, combined with the fact they hunt close to the colony, means gentoo chicks are fed more frequently and it's thought this is the reason they rear two chicks at a time rather than one like most other penguins. Here's a look at how their parents give them the best start in life...

Laying eggs
4 weeks before hatching
Females lay two eggs and the parents share incubation duties. The nest of eggs, known as a clutch, is kept at a snug temperature of 30-36 degrees Celsius.

Hatchling
0-28 days
For the first month the parents take turns hunting for food in the coastal waters while the other guards the chicks from predators.

Crèche phase
The chicks are now large enough to leave the nest and gather in 'crèches' while the parents hunt. They shed their insulating down and grow their adult feathers.

Nesting
6 weeks before hatching
The parents work together to build a circular nest of pebbles, foliage, sticks and feathers. Competition for the largest stones and the most well guarded spots is often fierce.

Annual moult
During the breeding season, adult penguins become thin and their feathers damaged. Once the chicks have fledged, the adults will spend weeks at sea fattening up before their annual 'catastrophic' moult.

Breeding
3 years
Every spring, the gentoos gather in small colonies and build nests of pebbles. They reach sexual maturity at the age of three and will often mate with the same partner every year.

Learning to swim
70-80 days
At 70 days old, the fledglings start venturing into the sea, but unlike other penguins, they don't leave the colony straight away. Their parents continue to feed them for a week while they learn how to swim.

Juvenile
1-2 years
Gentoos usually remain close to their breeding grounds all year round, although some have travelled as far as Australia and New Zealand.

Real STAR WARS worlds

You don't need to go to a galaxy far, far away to discover strange alien lands

MIMAS

STAR WARS WORLD: DEATH STAR

The moon of Saturn also resembles Star Wars' iconic planet killer

In the Star Wars universe, the Death Star was terrifying for its large concave dish, used to focus a planet-destroying super-laser. If that image still gives you nightmares, then you probably don't want to go to Saturn's moon Mimas. The moon is already interesting for the multitude of craters on its surface, but it's the Herschel crater that draws the comparison. Named after its discoverer in 1789, William Herschel, this crater spans 130 kilometres, and has a large central peak towering up to eight kilometres above the surface. Mimas itself is interesting for being the smallest gravitationally rounded body we know of, about 396 kilometres in diameter. It might be small, but that's still more than twice the size of the Death Star.

The Herschel crater on Mimas gives it an eerie resemblance to the Death Star

Building a Death Star

Why not build your own planet? Economic students from Lehigh University in Pennsylvania worked out the cost of doing so – and it's not cheap. They estimate that to build the first Death Star, which measures about 150 kilometres across, you'd need about 13,000 times the entire world's gross domestic product (GDP). This comes in at a rather hefty £541,261 trillion ($702,123 trillion), with a build time estimated at 833,315 years. On the plus side, we've technically got enough iron on Earth to build two billion Death Stars. However, it's thought that some asteroids are rich in metals, including iron, so instead of using Earth's resources, using asteroids to build it would be cheaper!

KEPLER-16B
STAR WARS WORLD: TATOOINE

The first world found with multiple suns

Who could forget the scene from *A New Hope* when Luke Skywalker looks upon the two suns of Tatooine in the sky together? Our real-world equivalent is Kepler-16b, the first planet observed orbiting multiple stars. Discovered in September 2011, the planet itself is probably unlike Tatooine, as it seems to be a gas giant with surface temperatures well below freezing. If you could survive on its surface, though, you'd see two stars in the sky. The planet orbits both in about 229 days, with one sun being much smaller than the other.

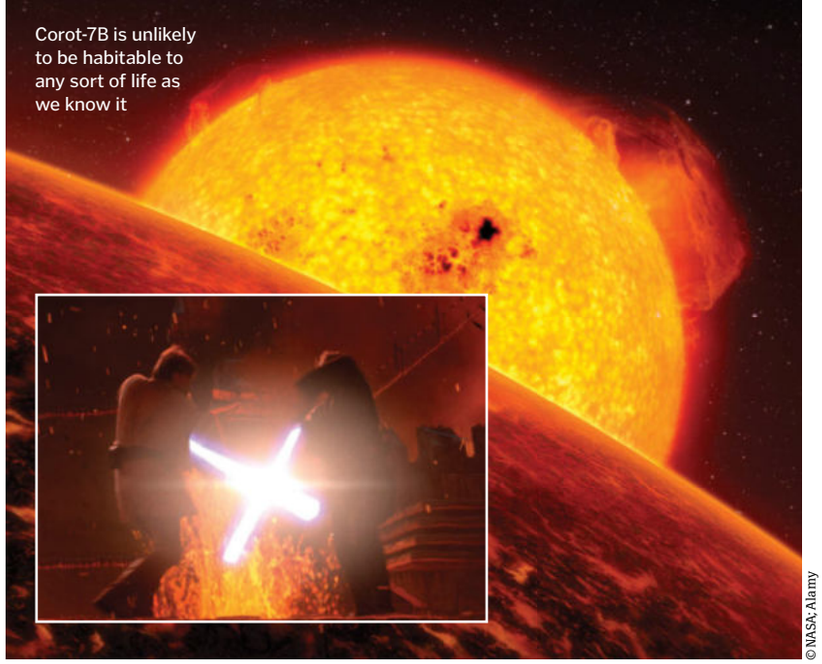
We now know of several planets that orbit two stars like Tatooine

"Just like Endor in Star Wars, exomoons could be habitable"

COROT-7B
STAR WARS WORLD: MUSTAFAR

The scene of the great, heated battle

If you are unfortunate enough to remember *Star Wars Episode III: Revenge of the Sith*, you'll also remember the battle between Obi-Wan Kenobi and Anakin Skywalker at the end, on the lava world of Mustafar. And if you've got a burning desire to recreate that battle for some reason, then we'd recommend travelling to Corot-7B. Discovered in 2010, this planet rotates around its star in an extremely tight orbit that takes just 20 hours. As a result, it has a surface temperature of up to 2,000 degrees Celsius. Corot-7b is one of the smallest known exoplanets at 1.58 times the size of Earth, but its molten surface would not exactly be welcoming to life.



Corot-7B is unlikely to be habitable to any sort of life as we know it

EXOMOONS
STAR WARS WORLD: ENDOR

We're sure they're out there, we just can't see them yet

In our own Solar System, six of the eight major planets have moons. It stands to reason, then, that planets elsewhere would have moons too, and just like Endor in Star Wars, they could be habitable. This fictional forest moon orbits a gas giant and is home to the lovable and somewhat controversially cute Ewoks. Astronomers think that real exomoons could be a good place to search for life, but the problem is that we can't see them very well at the moment. Our observational methods are pretty limited, so until better telescopes become operational, we might have to make do with watching Ewoks somehow defeat an army far more advanced than themselves.

Searching for exomoons

In 2014, astronomers announced they may have found the first exomoon

1. Transit
To find planets, we mostly look for dips in a star's light as a planet orbits.

2. No light
Exomoons can't be found with the transit method yet, because planets are too dim.

3. Microlensing
Instead, we look for small fluctuations in a planet's orbit from an exomoon's gravity.

4. Discovery
Astronomers used this to find an exomoon candidate around planet MOA-2011-BLG-262 in 2014 – although they could have mistaken its gravity for that of another star.

This planet's star is five times less massive than our Sun

OGLE-2005-BLG-390LB

STAR WARS WORLD: HOTH

Some like it hot; others like it really, really, cold

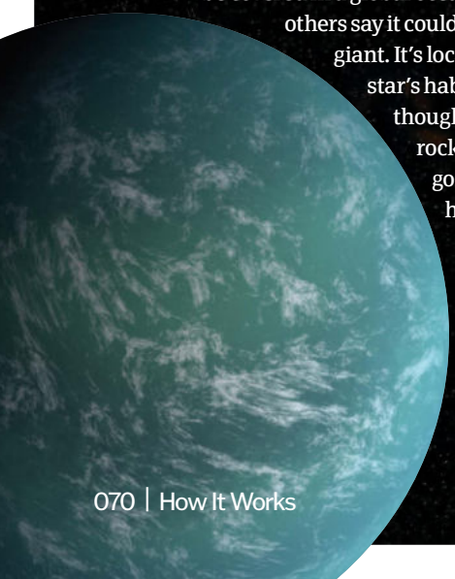
It might not have the catchiest name you've ever heard, but this exoplanet plays homage to one of the most famous Star Wars planets of all, the frozen world of Hoth. Found back in 2005, the planet is one of the most distant we know of, located 21,500 light years from Earth, towards the centre of the Milky Way. Its orbit around its star is comparable to being situated between Mars and Jupiter in our Solar System and, as such, lends itself to frigid temperatures. Despite having five times Earth's mass, the planet is thought to have a surface temperature of -220 degrees Celsius.

KEPLER-22B

STAR WARS WORLD: KAMINO

A distant water world, or a large ball of gas?

Remember Kamino? It's the water world from *Attack of the Clones*, where Obi-Wan travels to discover the Clone Army, amid crashing waves and a constant and torrential downpour. While we don't know a huge amount about Kepler-22b yet, it could be similar. This super-Earth, 2.4 times the size of Earth and found in 2011, was originally thought to be an analogue for our planet. Further studies, though, suggested it may be covered in a global ocean, while others say it could be a gas giant. It's located in its star's habitable zone, though, so if it is rocky, there's a good chance it has water.



Kepler-22b was one of the first planets to be found in a star's habitable zone

On the surface of Kepler-22b

A shifting orbit could have melted ice on the surface of this world

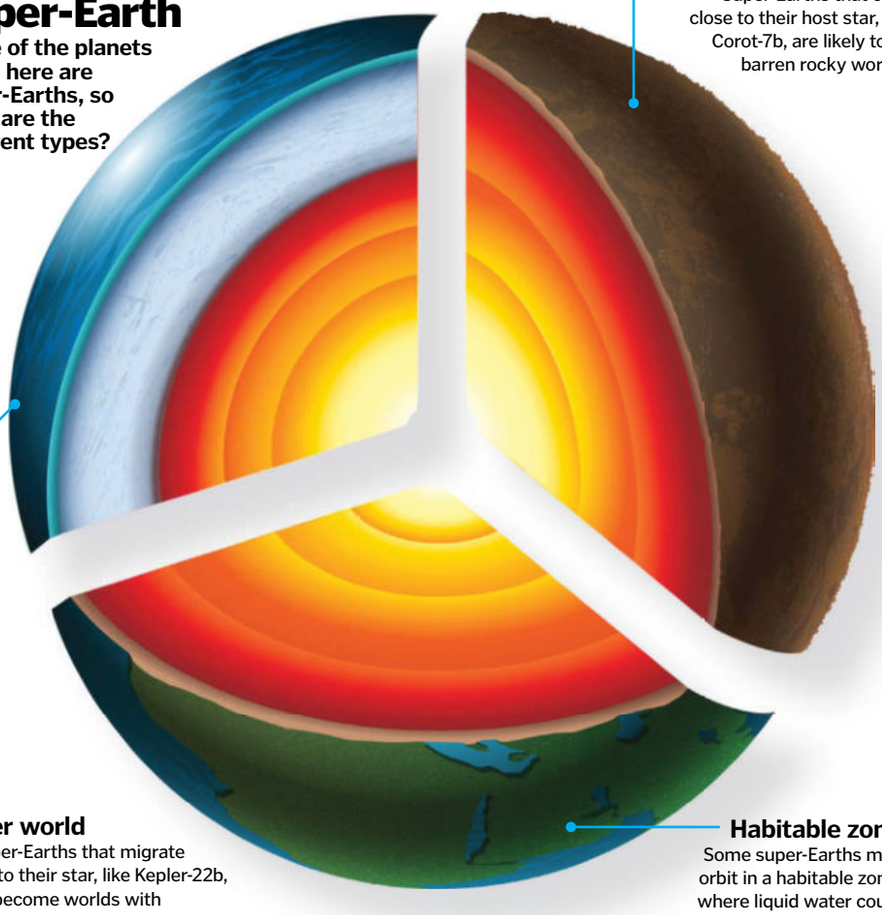
One year
At 289 days, Kepler's year length is similar to that on Earth.

Temperature
The surface temperature is now estimated to be 22 degrees Celsius.

Ocean
A surface that was once ice may have melted into a global ocean.

Types of super-Earth

Some of the planets listed here are super-Earths, so what are the different types?



Rocky
Super-Earths that orbit close to their host star, like Corot-7b, are likely to be barren rocky worlds.

Water world
Icy super-Earths that migrate closer to their star, like Kepler-22b, could become worlds with globe-encompassing oceans.

Habitable zone
Some super-Earths may orbit in a habitable zone, where liquid water could exist alongside land.

GAS GIANTS

STAR WARS WORLD: BESPIN

Could these worlds play host to floating cities in the clouds?

Of the several thousand planets we've found, many are gas giants. In fact, the four outer planets in our Solar System fall into this category. They have extremely thick atmospheres, with the planet being made mostly of gas such as hydrogen and helium. There's not technically a surface, only a small rocky core below layers of liquid metallic gas, so there's not much to stand on. But, like Bespin, if you could survive in the atmosphere, you'd be treated to endless clouds. Some suggest that, like Bespin, we could mine these regions for useful gases like helium-3 and hydrogen.

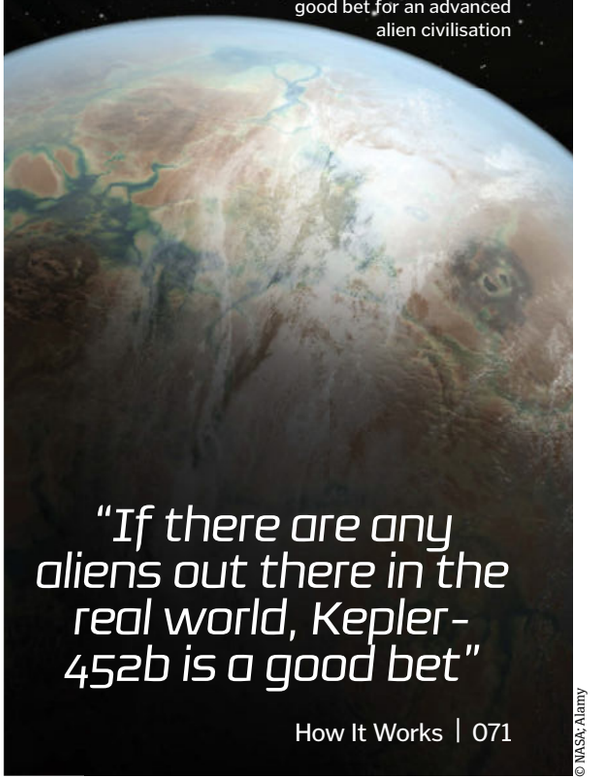
Jupiter, a gas giant, is the biggest planet in our Solar System

KEPLER-452B

STAR WARS WORLD: CORUSCANT

Does this world rule our galaxy with a planet-wide city?

Coruscant was the Imperial Centre of the Star Wars galaxy, known for its huge city that spanned the entire planet. If there are any aliens out there in the real world, Kepler-452b may be a good bet for a similar construction. This exoplanet, discovered by the Kepler telescope in 2015, orbits a star that's 1.5 billion years older than our Sun, meaning life there would have had much longer to develop. Crucially, the planet also orbits in the habitable zone of its host star, where liquid water can thrive. With water, there could be life. But the planet is 60 per cent larger than Earth, so even if there is life there, we have no idea what it might be like.



Kepler-452b might be a good bet for an advanced alien civilisation

"If there are any aliens out there in the real world, Kepler-452b is a good bet"

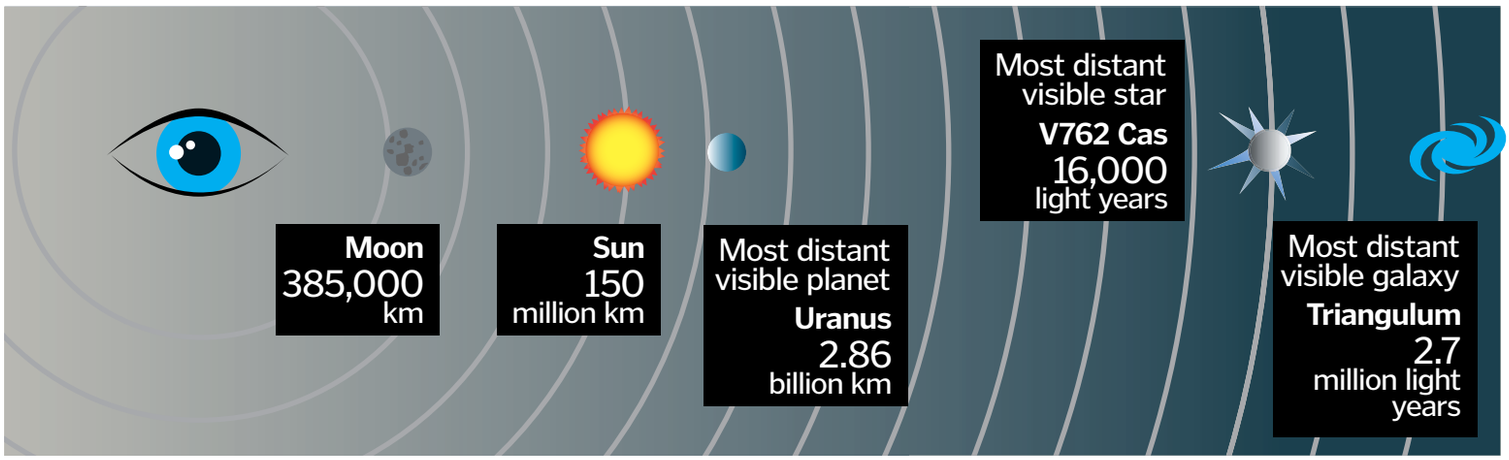
How far can we see?

Discover the most distant object visible to the naked eye in our night sky

You might think you need a telescope to explore the universe, but find yourself a suitably dark sky, free of light pollution, and even your naked eye can uncover the wonders of the universe – or, at least, our own galaxy.

When looking up at the sky, every star you are seeing is within the Milky Way. The only objects you might be able to spot that are outside it are the Andromeda Galaxy, the two Magellanic Clouds, and the Triangulum Galaxy.

This makes the latter the furthest object you can see, 2.7 million light years from Earth. You might be surprised that we can't see much outside our galaxy, considering how many stars are in the night sky. But that's just a measure of how vast space really is; there are an estimated 100 billion stars in our galaxy alone. Other galaxies are simply too far away to appear big in the sky, and require large telescopes like Hubble to be explored. In our galaxy, the furthest star you can see is likely to be V762 Cas, more than 16,000 light years away.



How to become an astronaut

Here's what you need to do to make it into space with NASA or ESA

If you want to become an astronaut, you'll need to be dedicated from an early age, and have a bit of geographic help, too. To become a NASA astronaut, you'll first need to be a US citizen of average height (between 1.49 and 1.93 metres). Candidates require a bachelor's degree in engineering, biological science, physical science or mathematics, as well as the ability to pass the NASA physical test.

If you would like to be a pilot or commander on a mission, there's a bit more to add to your application. The height range is even stricter (between 1.58 and 1.91 metres), and 1,000 hours of flight time is required. You can also find your way onto a mission as a payload specialist, where you are an expert in a particular field. This can include foreign nationals.

For the European Space Agency (ESA), the requirements are fairly similar, although flying experience isn't as important. There is an age limit of 37 though, so make sure you apply early.

Becoming an astronaut is tough, but hugely rewarding

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Testing the limits of spacecraft

Take a look inside the European Space Agency's high-tech testing facility

The European Space Agency (ESA) brings more than 20 countries together in pursuit of space travel, and its largest facility can be found at Noordwijk, on the west coast of the Netherlands. The European Space Research and Technology Centre (ESTEC) is the high-tech hub of the operation, responsible for making sure that all spacecraft and their payloads are fit to fly.

Travelling to space is a challenge. Spacecraft are exposed to extreme speeds, extreme temperatures, and extreme vibration. They will enter a vacuum, undergo weightlessness, and be pummelled with radiation, so before the spacecraft set off into these unforgiving conditions, the ESA team needs to make sure that they are ready.

More than 2,500 people work at ESTEC, designing the blueprints for new missions, developing new technology, and checking every spacecraft before launch. Each new item needs to be tested, and the facility is equipped to mimic the stresses of outer space as closely as possible.

The self-contained facility was specially designed to allow spacecraft to move from one area to the next, undergoing a sequence of tests to ensure that they are ready to fly. All the rooms are kept behind airlocks, ensuring that the craft remain clean and protected throughout their stay.

Inside the centre's various rooms, the equipment is shaken, spun, blasted with sound, frozen, bombarded with radiation and exposed to a vacuum. Each room is specifically designed to test a different aspect of the launch and space-travel process. For instance, the Large European Acoustic Facility acts like a giant music speaker, blasting satellites with the kind of volumes they will need to endure at lift-off. Next, the craft may be exposed to the extreme temperatures of space for a period of several weeks.

While the spacecraft and components undergo rigorous tests, the Data Handling Systems collect and analyse information from hundreds of sensors. Once they have passed every challenge that the Test Centre throws at them, the spacecraft are ready to make the dangerous trip into space.

Large Space Simulator
This room mimics the vacuum of space, bombards craft with radiation, and freezes them to temperatures far below zero.

Inside the Test Centre

A network of rooms allows spacecraft to be rigorously tested before they go into space

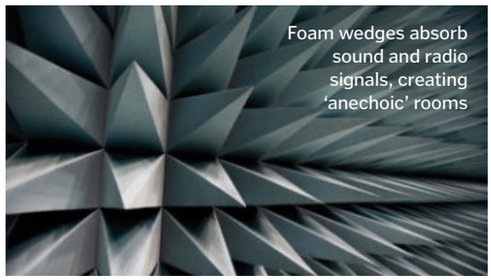
Electromagnetic compatibility facilities
These rooms are shielded from external radiation, allowing the electromagnetic emissions of the spacecraft itself to be tested.

The ESA Intermediate eXperimental Vehicle being shaken and stirred

Hydraulic shaker
This shaker, known as HYDRA, can simulate the vibrations of a major earthquake.

Vibrators
Shakers are used to put spacecraft through the intense vibrations that they will experience during launch.

Data-handling rooms
Adjacent rooms allow data to be analysed straight away, streamlining the testing process.



Foam wedges absorb sound and radio signals, creating 'anechoic' rooms

Compact Payload Test Range
This area allows satellites and other payloads to be tested in conditions that mimic those experienced in orbit.

Airlock
The entire facility is kept sealed and clean to prevent damage to the spacecraft.

Faraday cage
Metal on the walls, floors and ceilings continuously conducts electricity to screen out external radiation.

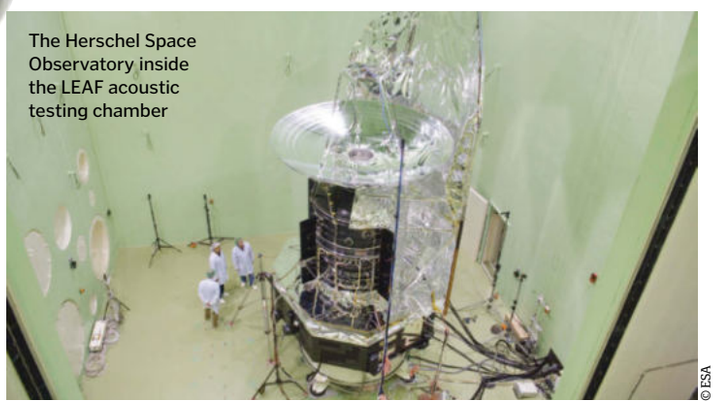
Large European Acoustic Facility
This spring-mounted, soundproofed room hits test vehicles with an intense wall of noise to simulate launch.

Sound proofing
The walls of the sound chamber are 0.5 metres thick, and made from steel-reinforced concrete to keep the sound contained.

Pushed to the limit

The Test Centre is equipped with an impressive arsenal of kit designed to test spacecraft and their payloads to breaking point. Physical properties machines weigh and measure the equipment, determining the centre of gravity and the moment of inertia. This can help to ensure that everything is balanced if the spacecraft needs to spin in flight.

Electrically powered shakers put the equipment through the intense vibrations of launch, while a hydraulic shaker is on hand for larger, heavier equipment. The Large European Acoustic Facility (LEAF) bombards satellites with intense sound, up to 156 decibels, to ensure that they will still be able to function after launch. And the most impressive room in the facility, the Large Space Simulator, plunges test equipment into a space-quality vacuum, complete with freezing temperatures and radiation that mimics the dangerous emissions of the Sun. Throughout testing, sensitive equipment gathers data about how the spacecraft are performing, ensuring that they will be ready for the real thing.



The Herschel Space Observatory inside the LEAF acoustic testing chamber

The story of life on Earth

Take a journey from the birth of our planet to the present day and beyond

A timeline of Earth

The key events in our planet's past, present and future

4.6 billion years ago
Earth forms as our Solar System begins to take shape from clouds of dust and gas surrounding the young Sun.

4.5 billion years ago
The Moon is formed.

4 to 3.8 billion years ago
Asteroids and comets rain down in abundance, in the Late Heavy Bombardment period.

3.5 billion years ago
The oldest known life arises – single-celled microorganisms. It's unclear if life began on the seabed, in open water or land.

3.4 billion years ago
Photosynthesis begins, as early microorganisms use energy from sunlight to turn molecules into sugars.

3 billion years ago
Plate tectonics begins on Earth, with the surface being split into giant plates of rock. We call Earth's first continent 'Ur'.

2.4 billion years ago
Oxygen enters the atmosphere as bacteria begin to produce the gas now essential to life. This is known as the Great Oxidation Event.

2.3 billion years ago
A lack of volcanic activity causes our planet to freeze over, becoming a 'Snowball Earth'.

2 billion years ago
Eukaryotic cells, which have a nucleus, mitochondria and membranes, begin to emerge on our planet.

1.5 billion years ago
The eukaryotes split into three groups that ultimately give rise to plants, fungi and animals.

900 million years ago
Multicellular life develops for the first time, although no one knows the exact process behind how this happened. Finding the answer could maybe help us find life on other worlds.

650 million years ago
The first complex life on the planet, most likely jellyfish, come into existence.

535 million years ago
The Cambrian explosion starts, a seemingly short evolutionary event of just 25 million years when most of the major animal groups emerge for the first time. The reason for this 'explosion' is unknown, but it may be partly down to better fossilisation now that animals have hard shells.

500 million years ago
Some animals make the move onto land. The first to do so are thought to be 'euthycarcinoids', the evolutionary link between insects and crustaceans.

250 million years ago
In the aftermath of a mass extinction, the dinosaurs emerge, and rule over Earth for almost 200 million years.

65 million years ago
The dinosaurs (along with pterosaurs and giant marine reptiles) are wiped out when an asteroid hits Earth, called the Cretaceous-Tertiary extinction event. This allows mammals to ultimately rule over the planet.

60 million years ago
The oldest known primates evolve in the hot and humid rainforests of Asia.

7 million years ago
The first hominid, our earliest ancestor, comes onto the scene. It's called Sahelanthropus tchadensis.

Present day

200,000 years ago
Finally, after quite a wait, the first humans (Homo sapiens) arrive. Within 200,000 years, they colonise almost every corner of the globe.

2,000 years from now
The Greenland ice sheets melt, drastically raising sea levels across the world.

100,000 years from now
Statistically, a large asteroid or a supervolcano is likely to have wiped out most of life on Earth by now, including us.

500 million years
Our Sun's temperature increases to a point where most of Earth's surface is a desert. Over the next few billion years, the largest remaining organisms on Earth will die out, leaving only insects and bacteria.

4 billion years
The Andromeda galaxy collides with the Milky Way, although it's unclear how this will affect our Solar System – aside from looking rather pretty in the night sky.

5 billion years
The Sun uses up the last of its hydrogen fuel. It may consume Earth or the planet may spiral out of its reach.

1 trillion years
This is the upper limit for when the Sun will stop radiating energy, becoming a cold black dwarf.

100 quintillion years
Earth's orbit decays and it falls into the Sun – whatever is left of both of them.

?
The last stars in the universe go out.

Past
Future

How long have humans been here?

In the grand scheme of things, a very, very short amount of time. If you could compress Earth's history into a single year, humans would have only existed for less than half an hour! In that relatively short time, we've managed to dominate most of the planet and started exploring other worlds too.

But unless we become a multi-planet species in the near future, it's likely we're eventually going to go the way of the dinosaurs. A mass extinction event will hit us sooner or later, and many experts think we need to colonise the Moon, Mars and maybe beyond to ensure the survival of our race.

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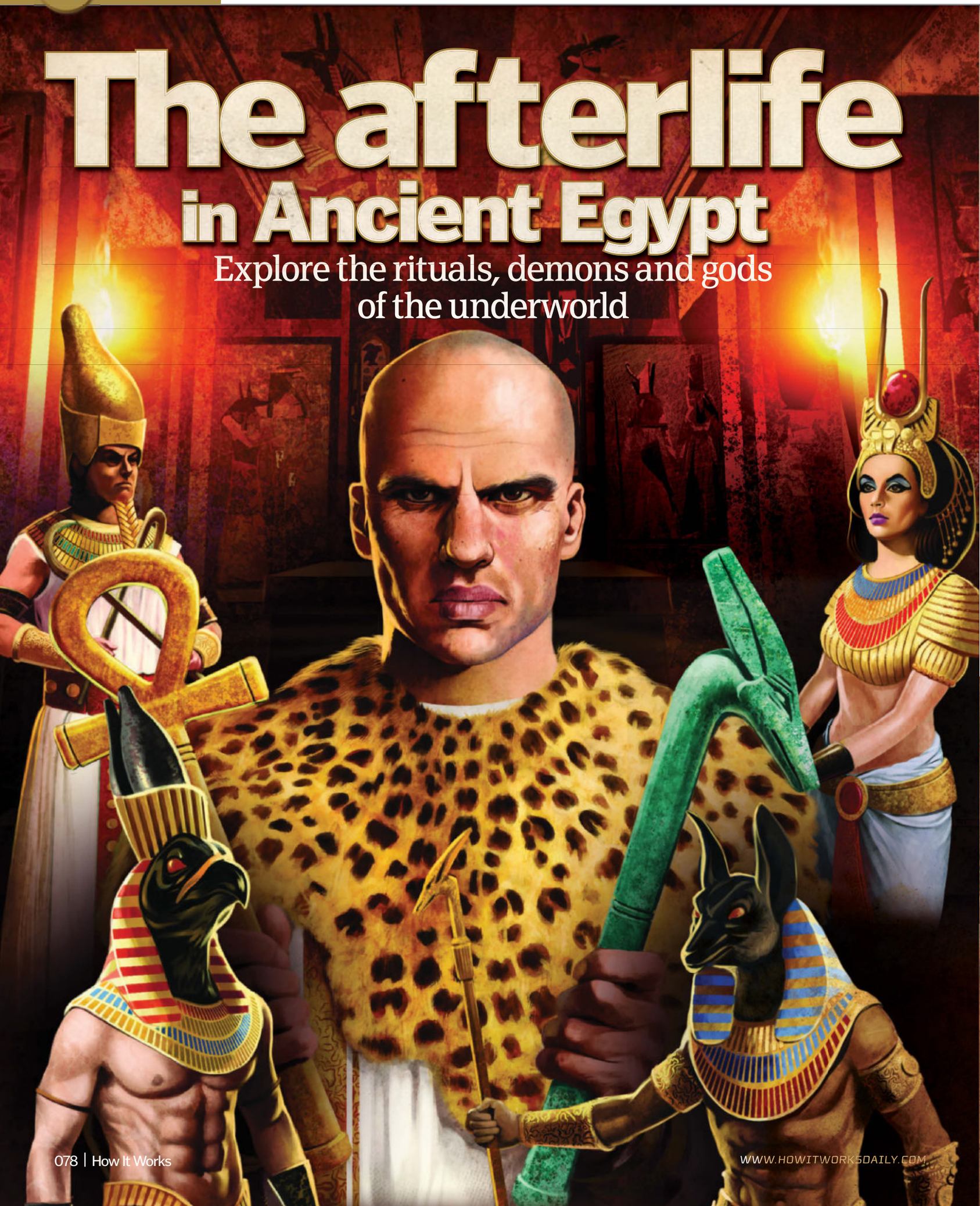
The afterlife in Ancient Egypt

Explore the rituals, demons and gods of the underworld



Few cultures conjure as much intrigue and horror as that of the Ancient Egyptians. The civilisation that sprung up along the banks of the Nile around 3000 BCE was among the most powerful on Earth. Though much of Egypt was an uninhabitable desert wasteland, the river was a life source that nourished soil and watered crops.

It gave birth to a society of farmers, doctors, builders and soldiers, whose achievements and inventions were greater than any seen before. They created one of the first writing systems, were among the first to practise science, and their art was a blueprint for the Renaissance masters. But the achievements that the Ancient Egyptians are best remembered for are their towering pyramids and gory mummification rituals. Death was an industry, and a booming one at that.

Religion was the pillar upon which this society was built, and it guided every aspect of life. They believed that there were many gods, each of which had a different role – from Sekhmet, the goddess of war, to Hapi, the god of the Nile, who brought the floods every year. But perhaps the most important element of the Ancient Egyptian religion was the belief in the afterlife. When a person died, it was thought that their soul could live on, but only if it successfully navigated the underworld. First it would have to battle demons and gatekeepers, before arriving at the Hall of Judgement where it would have to prove itself worthy of eternal peace. Those who passed the test could proceed to the Field of Rushes – a heavenly reflection of life on Earth. Those who failed would be forever restless, stuck in a purgatory that was worse than death itself.

Because of these beliefs, the Ancient Egyptians spent their whole lives preparing for their journey through the underworld. Not only did this mean avoiding sin as much as possible, but it also meant ensuring that their physical being had somewhere to rest, and it was accompanied by all of the things their spirit would need to thrive in the afterlife. Wealthy Egyptians spent years building tombs that were often more elaborate than their own homes, and filling them with priceless treasures. In Ancient Egypt, death really was an awfully big adventure.

"Wealthy Egyptians spent years building tombs more elaborate than their own homes"

Pyramids and tombs

In the early days of the Ancient Egyptian kingdom, pharaohs and other wealthy members of society were buried in mastabas. These were flat-roofed, rectangular structures with sloping sides, which helped to protect the grave from scavenging animals and thieves. But during the Third Dynasty, an architect named Imhotep came up with the idea of stacking multiple mastabas on top of each other, creating a much taller structure composed of a number of 'steps'. This would act as a gigantic staircase, allowing the deceased to ascend to the heavens. The first was called the Pyramid of Djoser, and it was built around 2680 BCE.

Over the next few hundred years, pyramids became the norm for pharaonic burials, and eventually the sides became smooth, not stepped. Kings and queens competed to build the tallest, most magnificent monuments, but this came at a cost. Huge amounts of stone were needed to build them, not to mention the costs of labour. Pyramids were also easy targets for gravediggers. By the time of the Seventh Dynasty, it was much more common for pharaohs to be buried in tombs carved deep into the rock.

The first Egyptian pyramid, built by Pharaoh Djoser, is 60 metres high

Nephthys

The mother of Anubis, Nephthys protected the dead as well as the reigning pharaoh.

The Book of the Dead

With so many demons, monsters and gatekeepers to tackle in the underworld, a magic spell or two could always come in handy. The Book of the Dead was a funerary text used from the beginning of the New Kingdom (around 1550 BCE), and contained spells that would help a person on their journey to the afterlife. Only the rich could own a copy, as they had to be specially commissioned and were written and illustrated by many scribes. The book was then placed in the coffin or tomb of the deceased, and extracts were inscribed on the walls, sarcophagi and amulets that were wrapped up with the mummy. Each spell had a different purpose. Some would help the deceased to identify different gods, while others would protect them from evil forces or give them control over the world around them.

Spell 17 of the Book of the Dead, which helps the deceased to recognise the god Atum

Making a mummy

The embalming process was long and gruesome, but the Ancient Egyptians believed it was necessary for the soul to survive

The key to eternal life wasn't just preserving the soul. Ancient Egyptians believed it had to return to its body regularly in order to survive, so that too would need to be kept intact. They also believed that the deceased must resemble the living as much as possible in order for the spirit to recognise its physical home. Initially, this was achieved by burying the dead in the desert, where the hot sand would dehydrate bodies and delay decomposition. But over time, the Egyptians developed an artificial method of preservation that would enable their remains to last for millennia. This was called mummification.

The first mummies date back to 2600 BCE, but it wasn't until around 1550 BCE that the most effective and well-known method of mummification was developed. This involved removing the deceased's internal organs, dehydrating the flesh, and then wrapping the entire body in linen bandages. The process took around 70 days and was extremely costly, so only the very rich could afford it. Poorer families were treated with another method of embalmment, which involved liquidising the organs with cedar tree oil and draining them out through the rectum, before placing the body in a salty substance called natron that would help to dry it out.

Because of the climate, embalmment was carried out as soon as possible after death. First the body was taken to an 'ibu', or 'place of purification' – usually a tent close to the Nile. Here it would be 'purified' using water and palm oil, representing the deceased's rebirth, and helping to keep them smelling sweet for longer. Then the body was taken to the 'per nefer', another tent where the embalmment would take place. Only priests were qualified to carry out this procedure, with the chief embalmer known as the 'hery seshta'. This man represented Anubis, the god of embalming and the dead, and often wore a jackal mask to show his importance. The hery seshta was responsible for wrapping the body and performing religious rites over the deceased – an element of the embalmment process just as vital as the physical preservation of the body. Thanks to the ingenuity of the Ancient Egyptians, we can now gaze upon the faces of men, women and children almost exactly as they were 3,000 years ago.

A beginner's guide

Follow these easy steps to create a mummy that will last for eternity

Step one

Purification
Before embalming can begin, the body is purified using water from the Nile and palm wine.

Washing the body
Washing the body symbolises a rebirth, as the deceased passes into the next life.

Removing the organs
An incision is made in the left side of the body, and the lungs, liver, intestines and stomach are removed.

Hooking out the brain
The brain is not thought to be important, and is hooked or drained out through the nose and discarded.

Step two

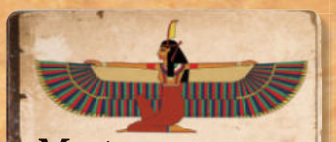
Keeping the heart
The heart is left inside, as it is believed to be the centre of intelligence, and needed in the afterlife.

Cats were worshipped by the Ancient Egyptians, so they were also mummified at death

Anubis
The jackal god, Anubis, was guardian of cemeteries and the god of embalming.

Step five

Wrapping
Linen bandages are used to wrap up the entire body. Liquid resin is used as glue.



Maat
As the goddess of truth and justice, Maat's role was to determine if a soul was fit for the afterlife.

Step four

Oiling up
Oils are rubbed all over in order to help the skin to stay elastic.

Saying a prayer
A priest recites prayers and spells over the deceased to help ward off evil spirits.

Dry stuffing
The body is washed and the natron scooped out. It is then stuffed with sawdust, spices and linen.

Storing
The organs are washed and then packed in natron before being placed in canopic jars.

Step three

Leaving to dry
Next, the body is completely covered in natron and left to dry out for 40 days.

Salting the insides
The body is stuffed with natron – a type of salt – which will absorb any moisture.

This mummy, on display in the Louvre, is that of a man who lived in the Ptolemaic period (305-30 BCE)

Funerals and burial

Egyptians departed this world with all their home comforts

Osiris
Osiris, depicted as a mummified pharaoh, was god of the afterlife.

Long before their deaths, wealthy Egyptians would build their tombs and pile them high with things they would need in the afterlife. From tables and chairs to chariots, jewellery and mummified pets, they could guarantee that their spirit would never want for anything. Food was just as important in the afterlife as it had been in their worldly one, so copious amounts of wine, fruit and grains were also buried with the dead. Even meat was included, which was often salted or even mummified to prevent it from rotting. If the worst came to the worst, they could always paint food on the walls – the Ancient Egyptians believed that in the land of the dead, depictions were just as edible as the physical products.

Also placed in the tomb were shabtis. These were small figurines, often made from clay, wood or stone, which would act as servants in the afterlife. Some people were buried with just one or two, whereas others – like Pharaoh Taharqa – were buried with over a thousand.

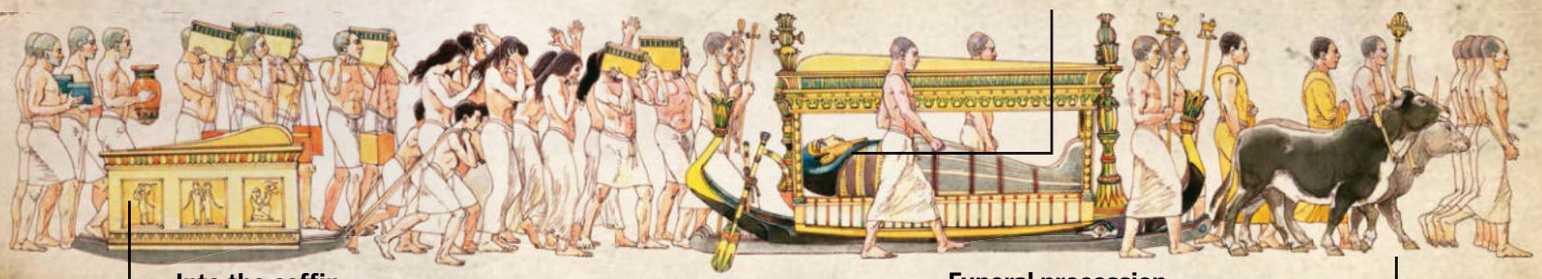
Poorer Egyptians had less elaborate tombs, while those at the very bottom of society were simply wrapped in cloth and buried in the desert with everyday objects like pots and perhaps a weapon of some kind. But everyone, rich or poor, was given a ceremony, as this was considered necessary in order for his or her spirit to pass to the underworld.

Wealthy Egyptians were given an elaborate funeral, during which the body of the dead was carried to the tomb accompanied by a procession of mourners and dancers. Two women called 'kites' were also present, whose job it was to mourn overtly. According to Ancient Egyptian religion, the greater a showing of grief, the better the soul would fare in the Hall of Judgement.

At the tomb, a priest performed the 'Opening of the Mouth' ceremony, in which the mummy was propped upright and a ceremonial blade pressed against the mouth. This would enable them to breathe, talk and eat in the afterlife. The action was repeated on the eyes and limbs to allow the spirit to see and move. The coffin was placed in a sarcophagus, offerings left, prayers recited and the tomb sealed.

A funeral fit for a pharaoh

These elaborate send-offs prepared the body for the lands of the living and the dead

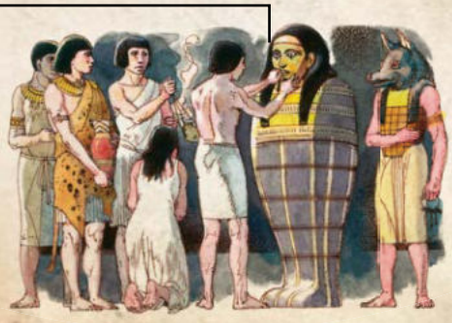


Death mask
A funerary mask resembling the deceased ensures that the spirit will be able to recognise its body.

Into the coffin
A painted 'cartonnage' case is attached to the mummy, then it is placed in a 'suhet' (coffin).

Funeral procession
A procession of mourners carries the coffin and grave goods to the tomb. Some of the mourners are paid to weep loudly throughout.

Opening of the Mouth
At the tomb, a priest performs the Opening of the Mouth ceremony, allowing the deceased to breathe and speak in the afterlife.



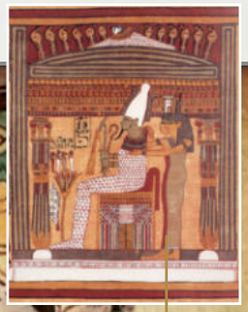
Sarcophogus
The coffin is placed in a sarcophagus – an alabaster box designed to provide extra protection.

Sealed with a spell
Both the sarcophagus and tomb are sealed before the priest casts a spell to protect them, known as the Curse of the Pharaohs.

Tutankhamun's meteorite dagger

In June, researchers announced that a dagger found by Howard Carter in the tomb of Tutankhamun appeared to be made with iron from a meteorite. The blade had puzzled archaeologists for decades, as ironwork was rare in Ancient Egypt and the metal had not rusted. An X-ray fluorescence spectrometer was used to discover its chemical composition. The high nickel content, as well as the presence of cobalt "strongly suggests an extra-terrestrial origin," and similar levels have in fact been found in a meteorite that crashed 240 kilometres west of Alexandria before or during the time of Tutankhamun.

The iron blade (right) is believed to be made from a meteorite



Journey to the afterlife

Securing a place in the heavens was easier said than done

No amount of money spent on tombs or time spent memorising spells could guarantee an Ancient Egyptian a place in the afterlife. First, their soul would have to conquer the obstacles and demons of the underworld, and then face the judgement of the gods in the 'Weighing of the Heart' ceremony. Only the worthiest souls could proceed to the Field of Rushes, where they would exist in pleasure for eternity.

The Ancient Egyptians believed that when a person was buried, their spirit departed their body and descended to the underworld (Duat). There, it must pass through 12 gates, each of which was guarded by a different deity, which the spirit must recognise and name. That may sound easy, but there were also monsters, demons and lakes of fire to contend with. The Book of the Dead provided a list of spells that would help the spirit to overcome these obstacles. If successful, the soul would pass into the Hall of Judgement, where it would have to prove its worthiness in front of 42 deities. The Book of the Dead also helped the spirit with the right answers to their questions, so that it could pass this stage of the test without being entirely innocent.

Isis

Along with her sister, Nepthys, Isis protected the dead, and was goddess of children.

Next, the spirit could proceed to the Weighing of the Heart ceremony. This was overseen by Osiris, the chief god of the underworld. The Egyptians believed the heart contained a record of all of the deceased's actions in life, so it was weighed against the feather of the goddess Maat to determine how virtuous they had been. If the scales balanced, the spirit was welcomed into the afterlife by Osiris. If the heart was heavier than the feather, it was thrown to the crocodile demoness, Ammut, and the soul was cast into the darkness, condemned to an eternity of restlessness. Of course, the dead could always rely on their trusty book for help. A simple recital of spell 30B could help to prevent the heart from giving away their murky past.

Those lucky enough to secure a place in the afterlife would experience the magnificence of the Field of Rushes. The dead would be granted a plot of land on which to grow crops, assisted by the shabtis they had been buried with, and look forward to a future of eternal peace.

Egyptians were buried with all their worldly possessions, including beds and chariots

In the underworld, the spirit would have to battle giant serpents and other monsters

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds that her job comes in very handy for taking part in quizzes!

Gemma Lavender

Gemma is the Editor of **All About Space**. She holds a master's in astrophysics, is an elected fellow of the Royal Astronomical Society and an associate member of the Institute of Physics. She is a STEM Ambassador and has been a keen observer of the sky for 15 years.

Despite new technology, most train drivers still need to know when to start stopping

How do train drivers know when to stop?

Ben Grey

Speeding trains can take miles to come to a stop so they have to start slowing down long before they get to a station. Some high-tech trains tell their drivers when to start slowing, but generally drivers are trained to understand the routes they travel on and will know when to start braking themselves. As the train slowly pulls into the station, signs and marks tell the driver exactly where to bring it to a complete halt. When the train is travelling between stops, trackside signals, similar to traffic lights, will order drivers to stop if there are problems on the line ahead. **TL**

The thyroid gland is located just in front of the windpipe

What does the thyroid gland do?

Liam Whitehead

The thyroid regulates functions around the body by releasing hormones into your bloodstream that influence metabolism, growth and development, and body temperature. These hormones act like chemical messengers, giving instruction to cells in other parts of the body. The pituitary gland in turn regulates the thyroid so that it produces the right amount of these hormones. An underactive or overactive thyroid can produce a variety of problems. In hypothyroidism for example, too few hormones are produced, causing your organs to become sluggish, slowing your heartbeat and digestion and resulting in symptoms including tiredness and depression. **AC**

These Canadian geese conserve energy for their long migration

Why do geese fly in a V-shape?

Mark White

Geese fly in a V-shape for two main reasons. Scientists tracked a flock of birds and discovered that flying in this formation probably makes it easier for the geese to communicate and keep track of each other. It also helps them save energy during long flights. The geese don't fly in straight lines; instead, each one flies slightly higher than the one behind it. This way, each one gains lift as it flies close to the bird in front, and the geese take turns being in the lead. Birds' heart rates have also been found to be lower when flying in a V versus flying solo. **SF**

As populations grew, they spilled out past old city walls

Why did civilisations stop building city walls?

Ethan James

Defensive walls were built as a barrier and a lookout point. They were useful for thousands of years, but as weaponry improved, and as people took to the air, it became easier to breach these defences. Populations also expanded, and it became less practical to keep everyone enclosed inside a physical barrier. However, although most settlements are not hidden behind walls today, people have not stopped building them. Patrolled border fences control the flow of people between countries, walls are used to mark out gated communities, and in regions of conflict they are erected as barriers to separate the two sides. **LM**

What is the powder on moth wings?

Emily Hale

Both moths and butterflies have a powdery substance on their wings that's actually a type of modified hair called a scale. These scales are probably mostly for looks, contributing to the pattern and colour of the wings. However, they may also help moths to regulate their body temperature – dark colours absorb light better – or camouflage them from predators. They may even help moths to modify airflow as they fly. Losing some of the powder probably wouldn't stop the moth from flying, but it's important not to touch the wings; they are very fragile and can be easily damaged. **SF**

The dust on these black moths' wings may help them keep warm by absorbing the Sun's rays

BRAIN DUMP

NASA's Cassini spacecraft uses a technique called a 'pi transfer' to complete a Titan flyby

What is pi and how is it used in everyday life?

Jo Ellis

Pi (π) is the 16th letter of the Greek alphabet and it represents a number that is used to find the area and circumference of a circle. Pi equals the circumference of a circle divided by its diameter, approximately equal to 3.1415.

Today, pi has a broad range of applications, including calculations for construction, quantum physics and even cake decorating! NASA uses it in many ways too, from working out the size of a spacecraft's fuel tank to finding out what asteroids are made of by calculating their density. **AC**

The Sun, the water cycle and our atmosphere generate weather events

What causes weather?

Zoe Smith

The Sun's uneven heating of our atmosphere, the water cycle and our atmosphere itself are responsible for creating weather. Solar energy creates the water cycle, an endless loop in which water evaporates into the air, forms clouds, and returns to Earth in the form of precipitation (rain, snow, hail or sleet). The Sun also creates wind by heating the air just above the ground. As this warm air rises, it's replaced by cooler air from the atmosphere. Not only is the atmosphere the staging ground for weather events, it also regulates the Sun's extreme temperatures. Changes in air pressure within the atmosphere affect the type of weather we see. The layers of air molecules press down on each layer below it, creating areas of high pressure and low pressure. Low pressure in the atmosphere leads to precipitation because the air rises slowly, bringing up water vapours that become clouds. High pressure sinks slowly and spreads out, keeping clouds from forming and giving us clear skies. **SF**

FASCINATING FACTS

Are water vapour and steam actually the same thing?

Steam is water that has been heated to boiling point and become a gas, whereas water vapour is tiny droplets of water suspended in the air, typically formed through evaporation. **AC**

Mist and fog are made of water vapour

Can Apple Macs get viruses?

Apple Macs can catch viruses, but they are safer from them than other types of computer. Not only is their software less vulnerable, but also there are far fewer viruses for Macs than there are for PCs. **TL**

Apple Macs are far less vulnerable to viruses than PCs

Are you really only six feet away from a rat, statistically?

Nobody's quite sure where that statistic came from, but even in the most populated urban city it's unlikely for a rat to be that close to you. According to one calculation, it's about 50 metres, or 164 feet. **SF**

Urban rats aren't as common as the saying suggests

Dry cleaning uses liquid chemical solvents instead of water

How does dry cleaning work?

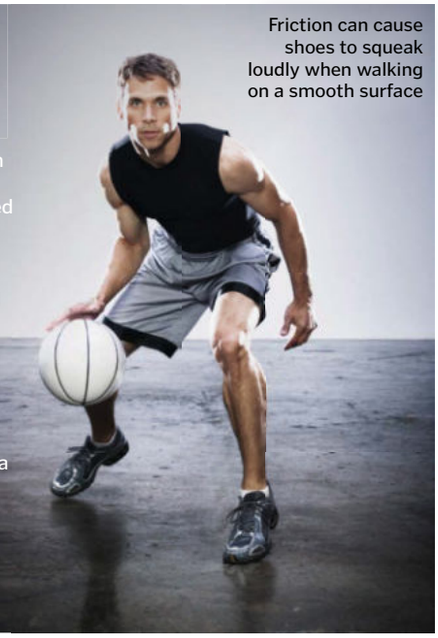
Chloe Bennet

Dry cleaning gets its name because it doesn't use water to clean clothes, but it isn't actually dry. Dry cleaning removes dirt using liquid chemical solvents. These solvents are better than water for removing some stains, such as oils. The dry cleaners will start by treating difficult stains with the right stain removers. Next the clothes get put into a special washing machine, which swishes them around in solvents that gradually lift off the dirt, and then the machine dries them with warm air. Finally the clothes are pressed, and look nearly as good as new. **TL**

Why do rubber shoes squeak on wooden floors?

Amy Brooke

The squeaking produced when walking with rubber soles on a wooden floor is a vibration caused by stick-slip friction. This occurs when two surfaces slide against each other in a jerky motion, alternating between sticking and sliding over each other. In an elastic material such as rubber, this causes energy to be stored and then released, resulting in a high frequency vibration: a high-pitched squeak. This often occurs at the interface between a rubber shoe sole and the floor, with surfaces such as polished wood, smooth tiles or vinyl particularly likely to provide just the right amount of friction to produce a squeak. **AC**



Friction can cause shoes to squeak loudly when walking on a smooth surface

How are mobility scooters powered?

Jonathan Appleby

The majority of mobility scooters are electric, powered by a rechargeable battery on board. This allows the user to travel around 45 kilometres on one charge, with spare battery packs allowing them to extend their range. Petrol-powered mobility scooters also exist but are noisier, more polluting and less popular than their modern electric counterparts. Mobility scooters have three, four or five wheels and are steered using handlebars, with a lever controlling speed. In the UK, these scooters are limited to 13 kilometres per hour on roads, or 6.5 kilometres per hour when travelling on pavements. Many product designers are harnessing technological innovations to update traditional mobility scooters and improve their stability, manoeuvrability and comfort, but also to make them more stylish and desirable. New designs include solar-powered scooters or even those with special adaptations for uneven terrain. **AC**

New technologies are giving mobility scooters a makeover

Mother's Day was never intended to become a commercial festival

What's the history behind Mother's and Father's Day?

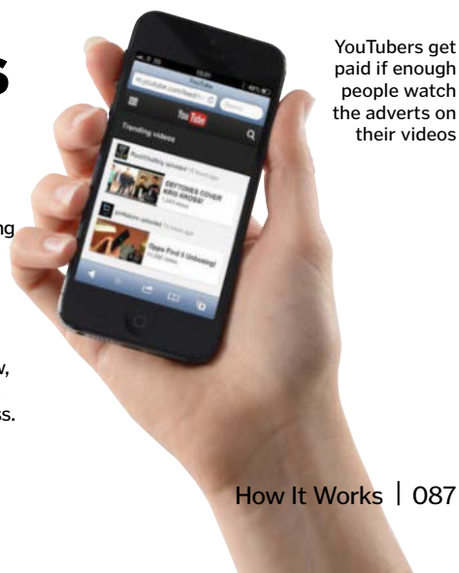
Estelle Franklin

In Britain, the day was originally a Christian observation, during Lent, when people flocked to their 'mother church' – the biggest church in their area. In America, the holiday began later, in the 1850s, when Ann Reeves Jarvis held clubs for mothers to help lower infant mortality. When she died in 1905, her daughter, Anna Jarvis, decided to arrange a day to encourage people to visit their mothers. Against Jarvis' wishes, the day quickly became commercialised, and people were encouraged to buy gifts. This was such a huge success that it led to Father's Day starting too. **LM**

How do YouTubers make a living?

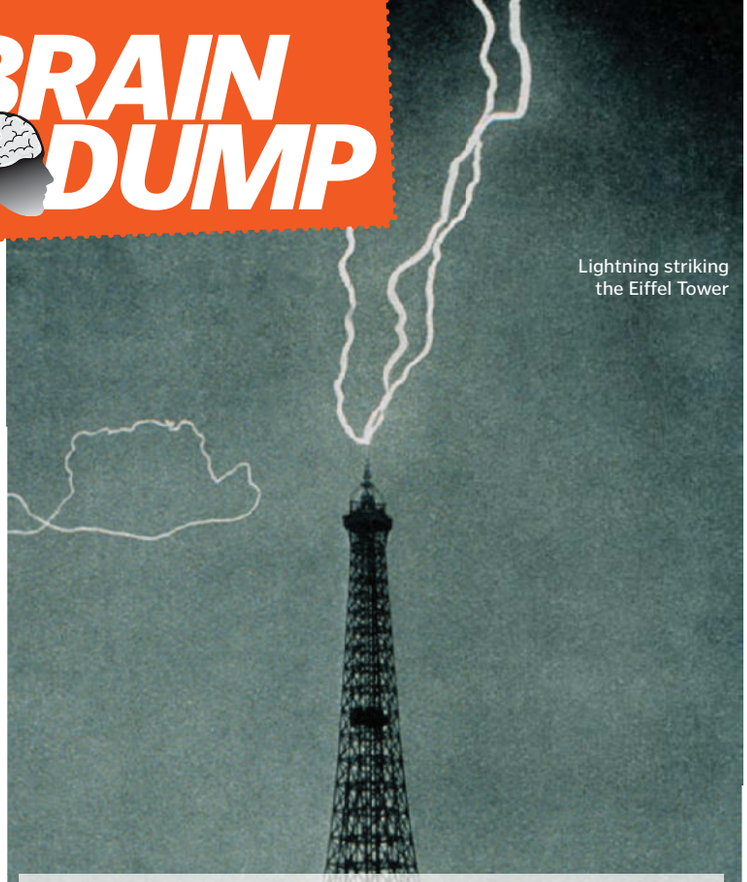
Freddy Mitchell

The most important way YouTubers make money is from allowing YouTube to put advertising on their videos. If enough people watch the adverts when they see the videos, or click to buy the products they are promoting, then they get paid. The more views, the more money they make! Companies may also offer sponsorship to successful YouTubers for product placements in their videos, and YouTubers with many followers can make their videos pay-per-view, or even ask for fan-funding donations. Although top YouTubers can make large sums of money from their videos, most make much less. It takes a lot of viewers to make a living. **TL**



YouTubers get paid if enough people watch the adverts on their videos

BRAIN DUMP



Lightning striking the Eiffel Tower

Why do we see lightning before we hear thunder?

Nathan Doyle

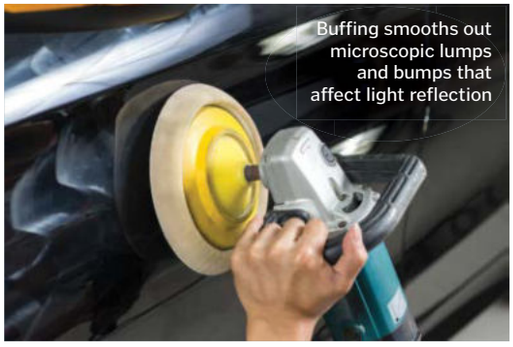
We see lightning first because light travels faster than sound. Light travels at about 300,000 kilometres per second, while sound travels at about 0.34 kilometres per second, depending on air temperature. The flash of lightning superheats the air around its path almost instantly to temperatures greater than 25,000 degrees Celsius. This superheated air is under a great deal of pressure. As it moves outward, the hot air compresses the air around it and this expansion creates a shock wave, which then becomes a sound wave. We hear the sound waves as loud booms and cracks, or thunder. **SF**

Hotel key cards store codes that tell electronic locks to open the door

How do hotel key cards work?

Joe Robinson

There are many types of key card system, but their principles are similar. When you check in, the hotel receptionist uses a machine to store a code onto a magnetic strip or computer chip on your key card. This code matches one stored by your hotel room's electronic lock, which reads the code when you insert the card, and switches on a small motor to unlock the door. To change the code for each new guest, the lock is either sent a new code by a network, or the card and lock have the same preset list of codes and can be instructed to use the next one in the sequence. **TL**



Buffing smooths out microscopic lumps and bumps that affect light reflection

Why does buffing polish make it shiny?

Martha Phelps

When light hits a surface, it obeys the law of reflection; the angle that it hits the surface at is equal to the angle that it is reflected at. When light hits a smooth, shiny surface, like a mirror, it all hits at the same angle, and is all reflected back in the same direction. This is known as specular reflection. However, when light hits a pitted, bumpy surface, it strikes all of the hills at different angles, and is reflected back at different angles too. This is known as diffuse reflection. While a polished surface might look smooth, it is covered in tiny imperfections. Buffing helps to even out these lumps. **LM**

Does drinking alcohol through a straw get you drunk quicker?

Lexie Olliman

The notion that you get drunk faster if you drink through a straw is based on two ideas: first, that you drink faster through a straw than if you were sipping your drink, and second, that by sucking you create a vacuum, which encourages the alcohol to turn to vapour, making it easier to absorb. It is true that inhaling alcohol vapour gets people drunk very quickly. However, the amount of vapour created by drinking with a straw is tiny, and as long as you drink at the same speed, there should be no difference in how quickly you get drunk. **LM**

Some people drink faster through a straw than from a glass

FASCINATING FACTS

What is petroleum jelly?

Verity Woodhall

It is a mixture of oils and waxes that are extracted as a by-product of the oil drilling process. It is purified before sale to reduce contamination. **LM**

Petroleum jelly was originally found coating equipment used to drill for oil

ASK THE ASTROPHYSICIST

Astronomy top tip
If you like observing both deep sky and planetary targets, use a Dobsonian telescope

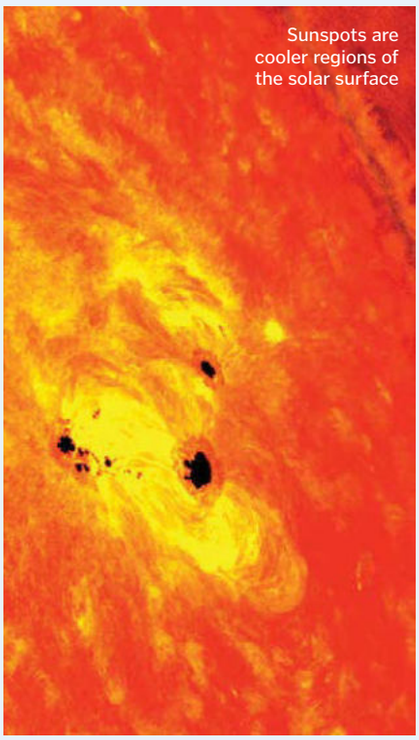
Gemma Lavender
Gemma is the Editor of **All About Space.**

Our planet rotates once every 24 hours

How does Earth spin?

Becky Garner

The reason why Earth spins on its axis is that it – along with the other planets in the Solar System – was formed 4.6 billion years ago in a rotating disc of gas and dust, which encircled an infant Sun. As the planets condensed out of the spinning disc, they took on some of its angular momentum, causing them to spin. When a giant asteroid collided with Earth and kick-started the formation of the Moon, the impact sped up Earth's spin so that a day lasted just a few hours, and it has been gradually slowing ever since. In 100 years, a day will be two milliseconds shorter than it is now!



Sunspots are cooler regions of the solar surface

Why does the Sun have spots?

Jess Moll

It's down to the Sun's magnetic field. The interior and exterior of the Sun spin at different speeds, which causes its magnetic field lines to get twisted and distorted. Occasionally, the magnetic field lines reach the surface, and push the hot gases beneath them. This creates sunspots – cooler regions of the solar surface that appear darker. The sunspots themselves are actually magnetic and appear in pairs with opposite polarity – like a magnet has a north and south pole. Sunspots come and go over a period of days or weeks.

Why can't stars be seen during the day?

W. Cooper

The glare of sunlight means that we're not able to see the stars during the day – they are still twinkling away though, even though they're not visible to us. During the day, sunlight causes the sky to appear blue – sunlight itself is white light, made up of a rainbow of colours. The blue element is scattered, causing our planet's atmosphere to look blue. This bright light overpowers the relatively faint light coming from the distant stars, so we are unable to see them during the day.

The Sun's brightness blocks our view of the stars during the day

Who invented the telescope?

Charlie Hobb

Dutch eyeglass maker Hans Lippershey is credited with the initial design, after he realised that lenses could be used to magnify far away objects. However, on hearing about the technique, astronomer Galileo Galilei made his own telescope and observed the moons of Jupiter.

Hans Lippershey filed for a patent for a telescope in 1608

Venus is often nicknamed Earth's evil twin

Why is Venus called Earth's evil twin?

Zoe Kingston

Being almost the same in size, mass and composition, Venus is often dubbed as Earth's twin. Both worlds have a metal core surrounded by a mantle of silica rock as well as a thin crust. However, that's where the similarities end. Thanks to its high surface temperature, crushing pressure and acid rain, the second planet from the Sun is often nicknamed 'Earth's evil twin'. Venus reaches temperatures of around 460 degrees Celsius, which is hot enough to boil lead, and an atmospheric pressure that's 93 times higher than what we experience.

What's happening on... Twitter?

Join **All About Space** every Saturday 6-9pm (GMT/BST) for a Q&A on Twitter where your astronomy questions will be answered live! Tweet your questions to **@spaceanswers** and follow **#StargazerSat**

@swamp_donkey77
@spaceanswers I have read that our Sun is part of a binary. What do you make of it?

Surveys haven't found this star yet, so we think it's becoming increasingly likely it doesn't exist – v. sadly!

@gau3tam7
@spaceanswers Is it true that Earth has two moons?

No, only one Moon. 3753 Cruithne is incorrectly referred to as a second moon but it doesn't orbit Earth.

@Sara99HG
@spaceanswers Is it true that you get older quicker in space than on Earth?

It's the other way around – you age more slowly in space due to a phenomenon called time dilation!

@0h4amuseoffire
@spaceanswers How can a comet that's only a few km in diameter lose so much mass when it heads toward the Sun and not disintegrate?

Comets don't usually lose much mass, so they can go around the Sun many times before they break apart.

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BOOK REVIEWS

The latest releases for curious minds

The Way Things Work Now

This favourite from the 1990s is still a success

- Author: **David Macaulay**
- Publisher: **Dorling Kindersley**
- Price: **£19.99 (approx $27)**
- Release date: **Out now**

If you're a fan of this magazine, then chances are you'll enjoy thumbing through this hefty tome too. Inside, you'll discover how just about every machine works, from the simple lever to the not-so-simple 3D printer. With this revised and updated edition of the much-loved *The Way Things Work*, the information is right at your fingertips.

This book is great for children and adults alike, and those who remember the older editions from the 1990s will recognise the distinctive style and informal but straightforward tone that the author adopts once again. Sensibly, the book is divided up into themes – including electricity and automation, and the mechanics of movement – and these themes are broken down into bite-sized pieces, so you can decipher everything from how a can-opener works to the way an automatic gearbox operates.

All of these elements combined make the text very easy to digest, instead of allowing the reader to become confused by technical jargon and irrelevant facts. The information is highly concentrated and well articulated.

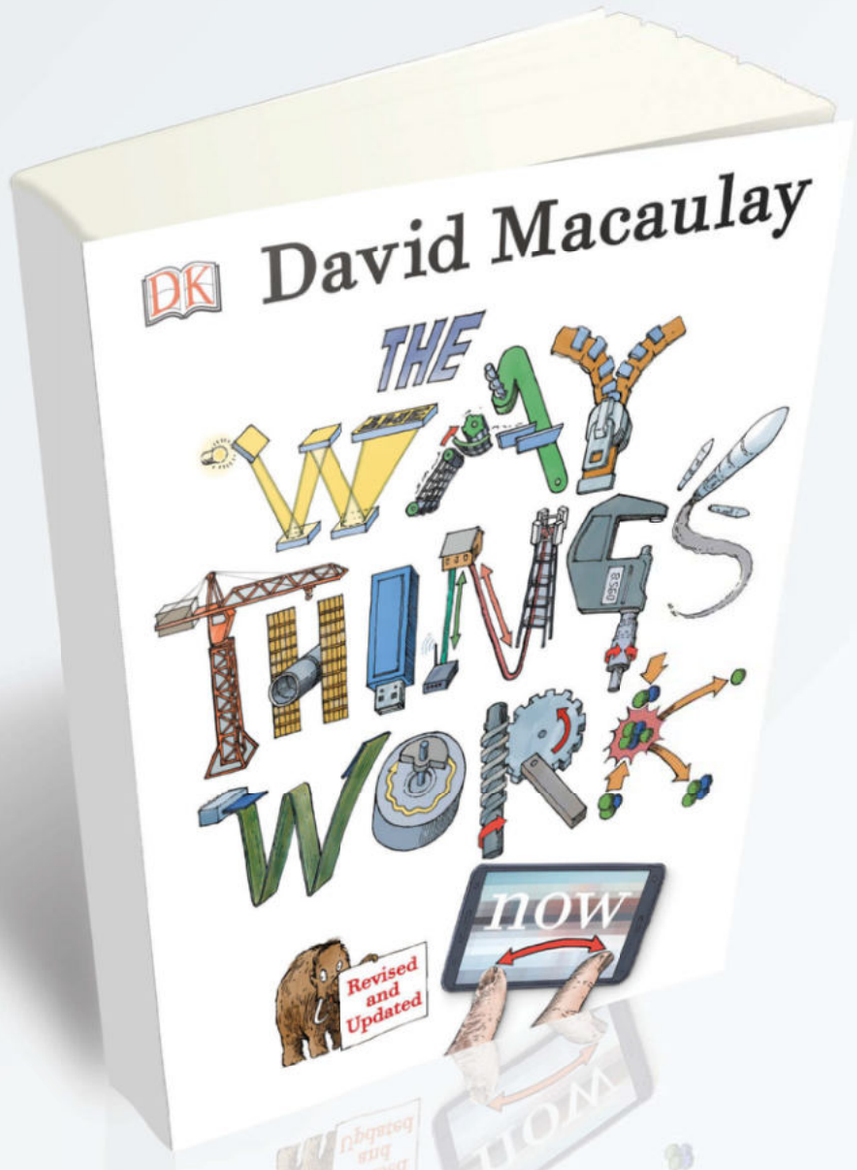
Packed with comic-style illustrations and diagrams, the pages appear rather cluttered and the information is a little lighter as a result. But what the book lacks in depth it makes up for in breadth, and you'll gain a wide appreciation of how technology has progressed.

And, of course, younger readers will love the cartoons of friendly woolly mammoths operating machinery – a quirky thread that ties all the topics together.

This is a great edition for all who have enjoyed Macaulay's work over the years, and those who are picking it up for the first time. The book, much like a typical story, starts off relatively simple, easing the reader in, and then towards the end picks up pace, confident in the knowledge that the reader has all of the relevant information from the previous chapters to delve deeper into the workings of various gadgets and gizmos.

Sticking to the humorous style of his previous work, Macaulay has done an excellent job of giving a classic book a modern makeover.

★★★★☆



YOU MAY ALSO LIKE...

Thing Explainer: Complicated Stuff In Simple Words

Author: **Randall Munroe**
Publisher: **John Murray**
Price: **£16.99 / $24.95**
Release date: **Out now**

Restricting himself to a vocabulary of just 1,000 words, Munroe manages to explain the inner workings of everything from tectonic plates to ballpoint pens.

Picturepedia

Author: **Dorling Kindersley**
Publisher: **Dorling Kindersley**
Price: **£20 / $29.99**
Release date: **Out now**

For those who are more visual learners, *Picturepedia* is absolutely crammed full of fascinating facts about history, technology, nature and much more, supported by more than 10,000 illustrations.

Tell Me How

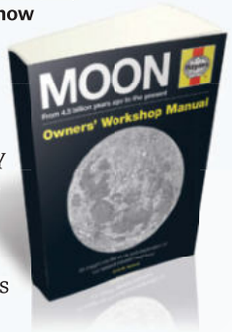
Author: **Octopus Books**
Publisher: **Bounty**
Price: **£7.99 (approx $11)**
Release date: **Out now**

How do spiders make their intricate webs? How does my memory actually work? How did the Olympic Games begin? Stock up on fun facts across a range of topics with this engaging and insightful book.

Moon Owners' Workshop Manual

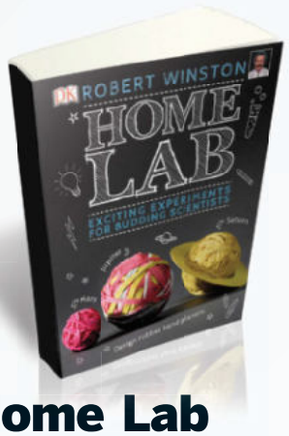
Not your standard Haynes Manual

- Author: **David M Harland**
- Publisher: **Haynes**
- Price: **£22.99 (approx $30)**
- Release date: **Out now**



We know what you're thinking – doesn't Haynes normally make DIY repair manuals for vehicles and household goods? Yes, but it also loves to branch out, and the result is a totally comprehensive history of our own Moon. It begins, as you may expect, with the first Egyptian and Greek philosophers who studied the motions of the celestial bodies in Classical times, and covers a huge amount of information, right up until the modern-day search for water on other planets or moons. It's written in lively, engaging language, and has some great insights – we particularly enjoyed how carefully worded the Vatican's statement from 1822 was, in which the Church began to realise it may be wrong about the Earth being stationary. Oops.

★★★★☆



Home Lab

Have some fun with hands-on science

- Author: **Robert Winston**
- Publisher: **Dorling Kindersley**
- Price: **£12.99 (approx $17)**
- Release date: **Out now**

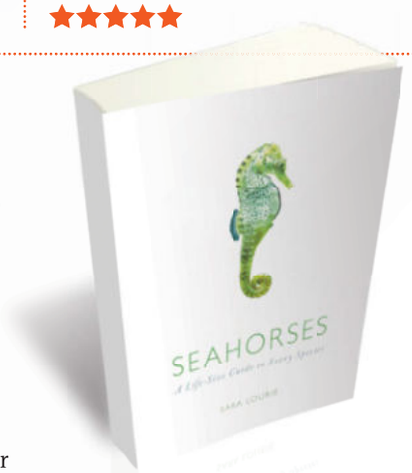
Buy this book and you'll never be bored again. A big claim, but it's absolutely packed with interesting experiments for you to try out at home, from creating a jungle in a bottle to folding the ultimate paper aeroplane. The experiments are all explained using clear text and photographs that make every step easy to follow. Plus, with some great science behind every experiment, the only challenge will be trying to work out which one you want to try first. Each page also tells you how long the experiment takes, and how difficult it is to complete, as well as neatly showing what you'll need so you can be ready before you start. It's a fantastic example of fun and education combined!

★★★★★

Seahorses: A Life-Size Guide to Every Species

Dive into a world of vertical swimmers

- Author: **Sara Lourie**
- Publisher: **Ivy Press**
- Price: **£16.99 / $30**
- Release date: **Out now**

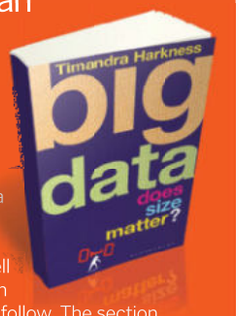


We've all seen seahorses in an aquarium or zoo, right? But with this book you'll now be able to know exactly which one it was you encountered. It's packed with details about all 47 species in the world, includes fantastic photography, and offers lovely silhouettes showing each creature at its actual size. However, the real focus of this book is on the factors that are putting seahorses at risk. Many are caught and killed for use in Chinese medicines, captured for aquariums, or dried and sold as souvenirs. *Seahorses* does a fantastic job of highlighting their plight – while it might not appeal to a huge number of people, it contains an important message.

★★★★☆

Big Data: Does Size Matter?

A huge topic covered in an accessible way



- Author: **Timandra Harkness**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $17.99**
- Release date: **Out now**

Big data is a big term, and it is one that gets thrown around a lot in the current era of smartphones, browser cookies and social media. Harkness takes a rather tough, technical subject and does very well to make it much more digestible, writing in a light, conversational tone that is easy to follow. The section about how much can be discovered from our smartphones is interesting – and a little worrying – while details about new ways to gather this kind of data (tracking car number plates and picking up conversations on the street, for example) give us a glimpse into a Big Brother-like future that unfortunately might not be all that far away.

★★★★☆

Isambard Kingdom Brunel

Inside the mind of one of Britain's greatest engineers

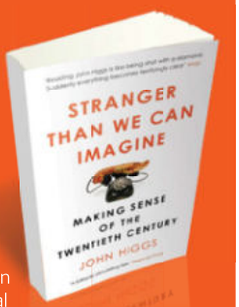
- Author: **Colin Maggs**
- Publisher: **Amberley**
- Price: **£20 (approx $26.60)**
- Release date: **Out now**

The life of Isambard Kingdom Brunel isn't exactly a secret – when someone has as much of an impact on engineering, writers are often drawn to them. But this life history is the first full-scale biography of the great man for more than 60 years, and it is very comprehensive. It's packed with stories, each written in an accessible way that will make even the most uninformed reader feel welcome. Newcomers to Brunel's work and long-time fans alike will find plenty to enjoy here – it's clear within a few pages that there was a lot more to the man than building boats, bridges and tunnels.

★★★★☆

Stranger Than We Can Imagine

A unique history of the 20th century



- Author: **John Higgs**
- Publisher: **Orion Publishing**
- Price: **£9.99 / $16.95**
- Release date: **Out now**

The 20th century was well-documented, but Higgs attempts a less commonly trodden history here. The century is broken down into a series of chronological cultural themes, with each chapter being further broken into analyses of key figures. The book begins by explaining how the certainty of the British Empire was destroyed at the beginning of the century, both by breakthroughs in quantum theory and World War I. Higgs' style is irreverent, intelligent and funny, and the topics are covered so well that this is a surprisingly accessible history.

★★★★★

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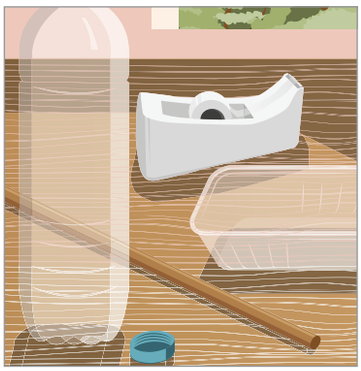
Create a DIY water wheel

Harness the power of H_2O with a handful of household items



1 Prepare your kit

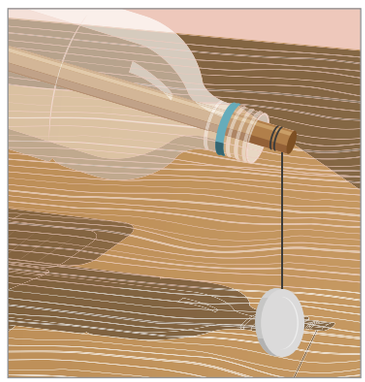
To create a water wheel, you'll need a two-litre plastic bottle, a long wooden dowel, plastic food trays and tape. Water wheels have been used for hundreds of years to transfer energy from water into other kinds of power. For example, water mills built next to rivers used the kinetic energy to grind grain into flour, so it could be used to make bread and other foods.

2 Create your buckets

We can create our own water wheel to discover how these machines work – albeit on a much smaller scale. To start, you need six small, plastic food trays, around 10cm long, 5cm wide and 3cm deep. Tape these securely to the plastic bottle at intervals, with the open sides all facing the same way. As you pour water on these, the bottle will turn.

3 Add an axle

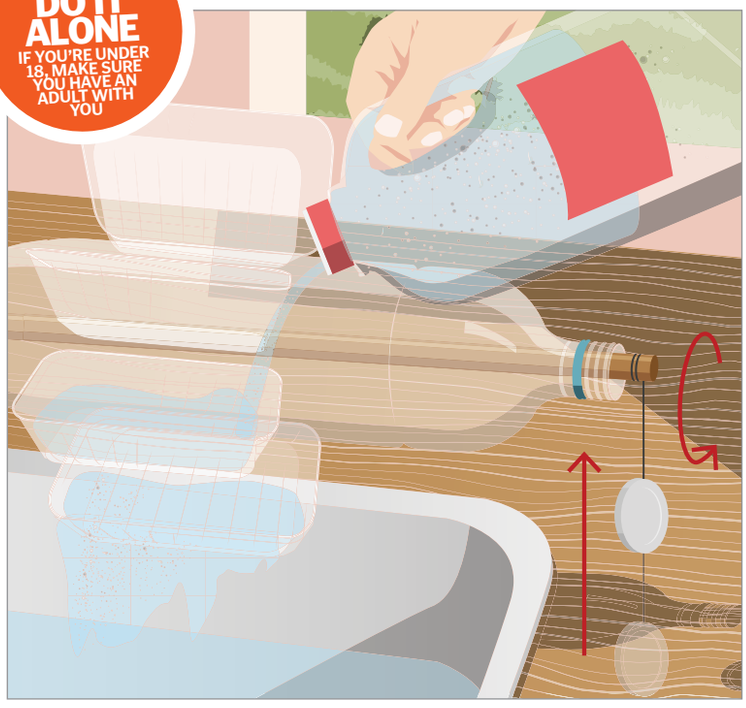
To make it a proper 'wheel', you need to add an axle through the centre of the bottle. We're going to use a long piece of dowel as the axle, and you need to punch a hole through the centre of the lid and the bottom of your bottle. Use something sharp, and ask an adult to help if necessary. When the hole is made, use tape to secure the axle in place at both ends.



4 Add a spinning weight

Now you can add a weight to one end of the axle. Attach a large piece of Blu-Tack to a piece of string, and tie it onto the axle – as your bottle turns, this weight will rise. If you like, you can also create a 'stand' for your wheel, and rest each end of the axle on it, but it might be easier to ask a couple of friends to help you out and hold it loosely at each end for you.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



5 Pour for energy

Pour water into one of the trays attached to your bottle. Gravity will pull the tub downwards. The stream of water will then start to fill the next tray, and the bottle will keep turning. You'll see the weight begin to rise as the axle turns, as the kinetic energy produced by the water is transferred into potential energy in the weight. Imagine this on a huge scale – that's a lot of energy!

In summary...

Water wheels have come a long way since their humble origins. Now, machines like this are used in huge hydroelectric power stations; river water is held back in dams and as the water is let through, it turns big wheels, which generates electricity for thousands of people!

NEXT ISSUE
- Soap-powered boats
- Make a wind catcher

Make fizzy sherbet

Concoct this fun snack at home, using some amazing science

1 Mix your sherbet

Sherbet fizzes as chemicals react with saliva to produce gas, which causes a tingly sensation. You can create this effect with just citric acid and bicarbonate of soda, but that wouldn't taste very nice! Add three dessert spoons of soft icing sugar to a bowl, then one teaspoon each of citric acid and bicarbonate of soda. Stir well for a good mix of tingle with a taste of sugar!

2 Give it some flavour

While this will taste nice, make the mixture more appetising by adding two dessert spoons of jelly crystals, in whichever fruity flavour you like the most. You could mix in popping candy for a more tingly sensation on your tongue, or some 'hundreds and thousands' for a bit of crunch while eating your sherbet. It's totally up to you, but these are all great additions!

3 Feel it fizz!

Once you've added all the desired ingredients, you can give your mix a try. Lick your finger and dip it into the mixture so that the sherbet sticks to it. Taste it and you will feel the citric acid and bicarbonate of soda react with your saliva to produce a little bit of carbon dioxide gas, creating a bubbly, tingly sensation on your tongue. To increase the feeling you can add more bicarbonate of soda into the mixture, but bear in mind that this might affect the flavour, so do it gradually.

In summary...

The citric acid and bicarbonate of soda react very slowly when they are both in powder form, but when they dissolve in your saliva, the reaction goes much faster. This is known as an acid-base reaction, and it produces lots of tiny bubbles of carbon dioxide, which create that fizzy sensation on your tongue!

Illustrations by Ed Crooks

Kitchen friendly
Triby features a robust splash-proof and dirt-proof design, and strong magnetic back to attach to the fridge.

Sticky notes
Messages, emoji and freestyle drawn doodles can be sent to Triby via its dedicated app and are displayed via the E-Ink display.

WIN!

A connected kitchen speaker worth £159

Using Amazon's Alexa Voice Service, you can get Triby to play music, set alarms, relay the news and weather and control smart home devices using just your voice. Just say 'Alexa' and then your command, and Triby will respond.

What does SAS stand for?

a) **Super Army Soldiers**

b) **Stellar Awesome Spacemen**

c) **Special Air Service**

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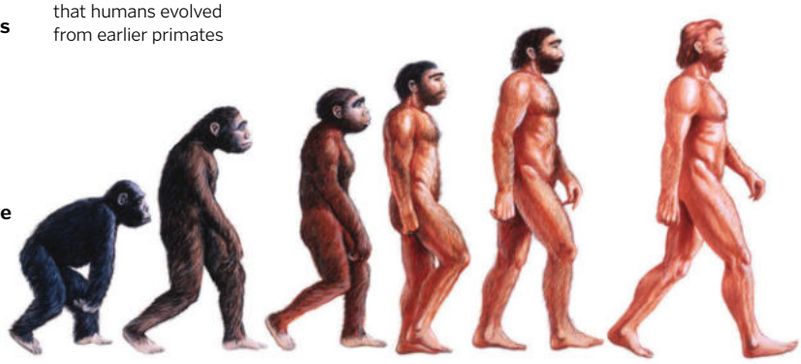
WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
HAYNES MOON MANUAL
Discover everything there is to know about our planet's satellite in this unique and innovative guide.

Letter of the Month

Human evolution

Dear **HIW,**
I am an avid reader of books. It was a delight when my mum bought a **How It Works** magazine. I love science, technology and gadgets, and I have already become a huge fan of **HIW**. I'd like to ask: Why is there more than one theory to explain how mankind evolved?
Zoey Davina

Evolution is the best scientific theory we have for how today's living things came to be. There is much evidence that today's creatures evolved from simpler life forms over time, like humans evolving from primates. Looking at fossils of creatures from millions of years ago, we can see different stages in evolution over time. Fossils show that there were primitive, human-like primates long before there were humans, and evolution explains how these creatures probably evolved into humans over millions of years. However, there is still much debate between evolutionists and people who believe that humankind was created by a god. Some people believe religion more than science, but others question the evidence and ideas, as evolution is not perfectly understood. The debate over life's origins continues and the theory of evolution is itself slowly evolving.


There is much evidence that humans evolved from earlier primates

What's happening on... Twitter?

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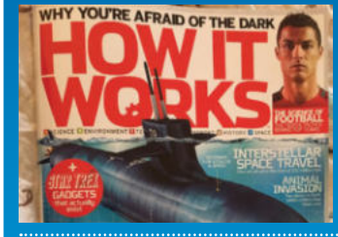
@gus_hodgeson
@HowItWorksmag Why can humans not have red eyes and is there any animal that can?

@Sara99HG
@HowItWorksmag It has arrived! "The science of fear" was fantastic! Incredible articles!



@elonmusk
Working on Top Secret Tesla Masterplan, Part 2. Hoping to publish later this week.

@ProfBrianCox
It really is worth watching The Sky at Night Juno Special on [BBC] iPlayer. It's brilliant.

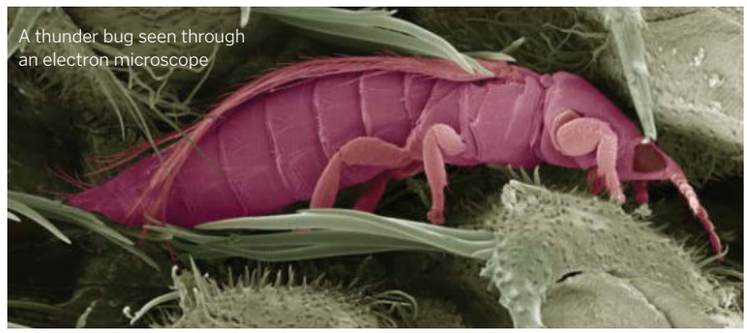
@POTUS
Incredible! After a 5-year journey, we're up close and personal with our Solar System's largest planet. Welcome to Jupiter, @NASAJuno!

Why do we have different languages?

Dear **HIW,**
I love your magazine; every month I find new and amazing facts. I was wondering why the whole world doesn't speak the same language? Wouldn't it be easier?
Isobel (aged 15)

Some believe that long ago, we all spoke the same language. However, the world was far less connected than now, so ancient tribes in different places probably developed their own languages, which have evolved into the ones spoken today. Having many languages isn't all bad. Each one might be better adapted to the places where it is spoken. The 19th century Polish doctor Ludwik Lejzer Zamenhof created an international language, Esperanto, hoping people would fight less if they understood each other.


Zamenhof hoped Esperanto would unite the world but only 2 million people speak it


A thunder bug seen through an electron microscope

LED illumination

Dear **HIW,**
I love this magazine and read it every month. My question is: How do thunder bugs know when a storm is brewing, and why do they come out then?
Oliver Ikin (aged 9)

Thunder bugs, also known as thrips, are tiny insects that appear in swarms near the ground when storms approach, but scientists are not entirely sure of why they behave this way. They might be able to detect the changes in air pressure that accompany storms, and then swarm around looking for shelter. Other scientists suspect that the electrical fields created by a thunder storm might make it difficult for thunder bugs to fly properly, meaning we see more of them near the ground as a storm brews.

What exactly is outside space?

Dear **HIW,**
I would like to say how much I love your magazine; it teaches you lots of new things that you thought you would ever know! Your magazine has made me more interested in science. My question is: What is above space?
Scarlett (aged 8)

We don't know what's above or outside space, but scientists have many theories. Our universe might be just one of many universes surrounding each other, or there may not even be an 'outside' of space. It could be that the universe stretches on forever in every direction. Weirdly, the universe might not be infinite, but just shaped so it seems it is. That would be a bit like running around inside a ball – it has no edges and seems to carry on forever.


Some cosmologists propose the universe could be a doughnut-shaped torus

Correction
Errors appeared in Issue 88. Page 46 included mismatched hammer images – for the correct labels look for our web post at the link below. An answer on page 89 incorrectly refers to Newton's Third Law as the Second. Facts matter to us and we are sorry to have let you down.

HOW IT WORKS

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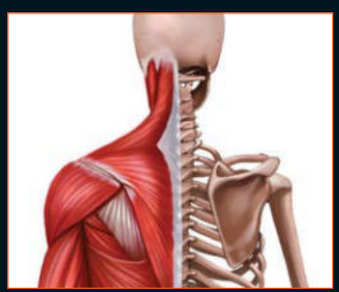

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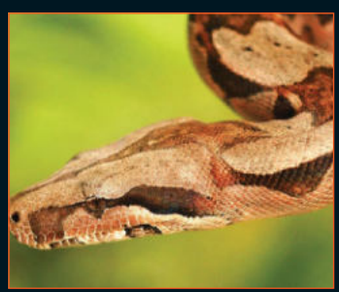

Discover the secrets of slithering snakes

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FAST FACTS

Amazing trivia to blow your mind

$127bn The projected worth of the drone industry in 2020

45KG THE WEIGHT OF THE GEAR THAT A US SPECIAL OPERATIONS SOLDIER CARRIES, AROUND THE SAME AS 13 BRICKS

98% The amount of gorilla DNA that is identical to a human's

THE VENOM OF A BLACK WIDOW SPIDER IS 15 TIMES STRONGER THAN A RATTLESNAKE'S

15.95 The number of days it takes Titan to orbit Saturn

The Trident missiles are up to 30 times more powerful than the atomic bomb that was dropped on Hiroshima in 1945

NO SPECIES OF BAT IS BLIND

36 SECS The average delay of the Japanese Shinkansen bullet train between Tokyo and Osaka

$10bn THE ESTIMATED VALUE OF THE STAR WARS FRANCHISE

THERE ARE 200 MILLION INSECTS FOR EVERY HUMAN ON EARTH

436 The number of skyscrapers set to form London's new skyline over the next few decades

CLEOPATRA VII LIVED CLOSER IN TIME TO THE FIRST MOON LANDING THAN THE BUILDING OF THE PYRAMIDS

7 MILLION TONS The amount of rock excavated while digging the Channel Tunnel

2000+ THE NUMBER OF DIFFERENT GODS ANCIENT EGYPTIANS WORSHIPPED

277 The number of attempts it took to clone Dolly the sheep

42 The minimum number of press-ups a hopeful Navy SEAL candidate must be able to do in two minutes flat

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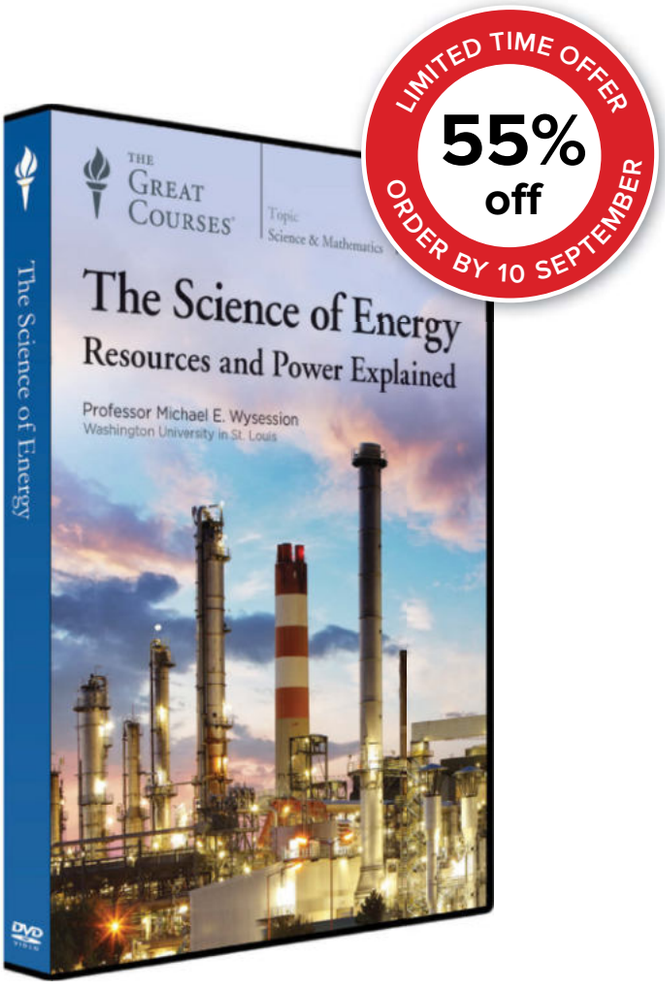

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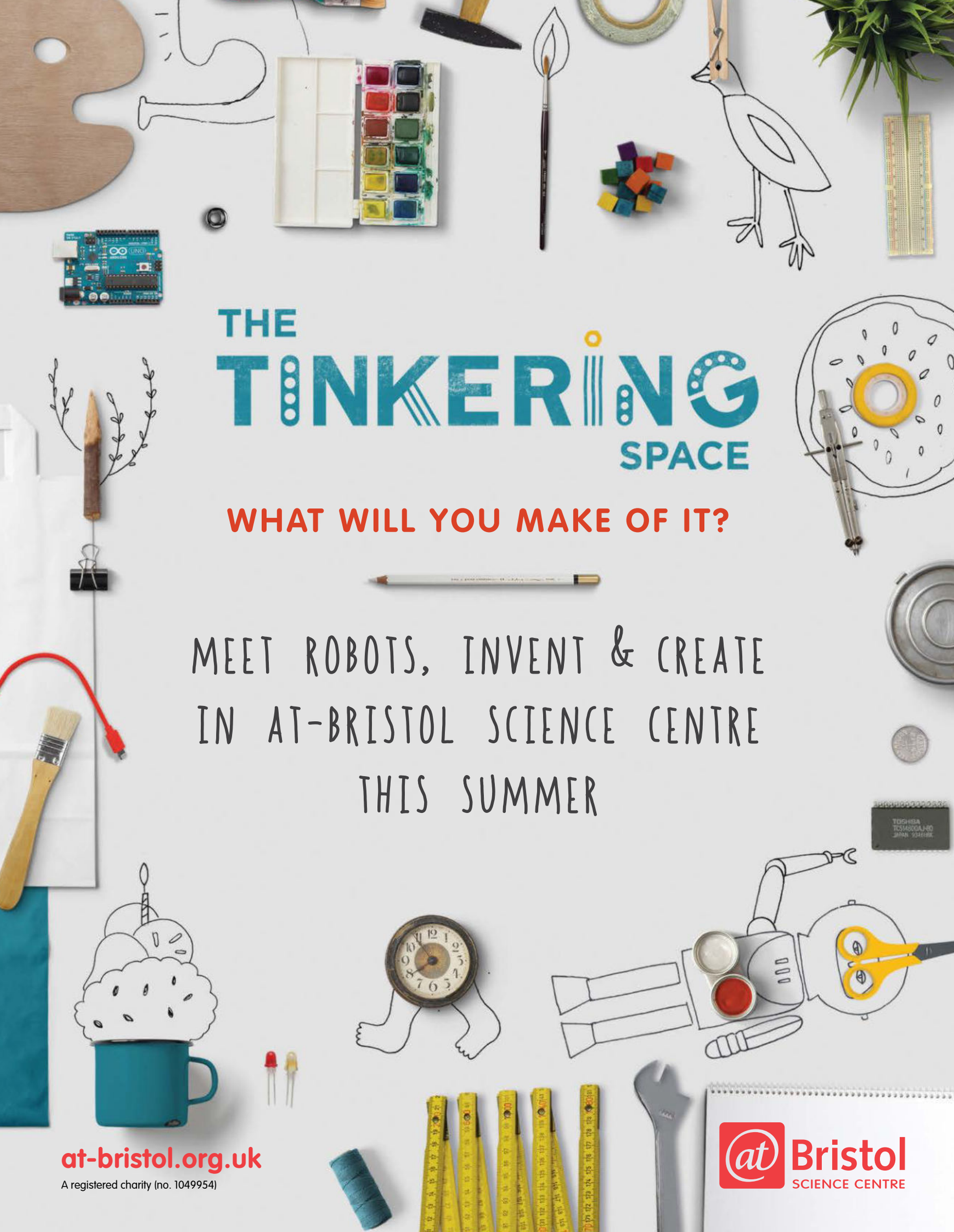
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